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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

J. G. SMITH SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No 6.

To acquaint the public with what is necessary to be known in regard to the cultivation of vanilla in Hawaii the following paper has been prepared by Mr. Frank E. Conter. This is in part a record of observations made on plants grown here, and in part a compilation from the best works on Vanilla culture, especially Lecomte and Chalot, "Le Vanillier;" Galbraith, "Vanilla Culture;" and, Dr. Preuss, "Expedetion nach Central und Sud-Amerika."

Experiments in curing vanilla were made at this Station, using pods from plants grown by Hon. S. M. Damon at Moanalua. Mr. Conter has also visited the Edwards Vanilla Plantation on Hawaii, and has noted the conditions there, and in the numerous localities around Honolulu where this plant is making a thrifty growth.

The vanilla plant was introduced into Hawaii many years ago, direct from Mexico and also from Tahiti, Samoa and Fiji. The prime requisites to make the cultivation of this crop a success are: the selection of a suitable location, at low elevation and where there is protection from the full sweep of the trade winds; and, of even great importance, constant and careful attention to every detail of cu tion, pollination, curing and fermentation, until the selected an ished product is ready for market. The sole difference between crop of vanilla at $1 a pound and one at $10 to $15 is the care giv to the crop from the time the cuttings are planted until the finished product is marketed.

JARED G. SMITH,
Special Agent in Charge.

Honolulu, Aug. 10, 1903.

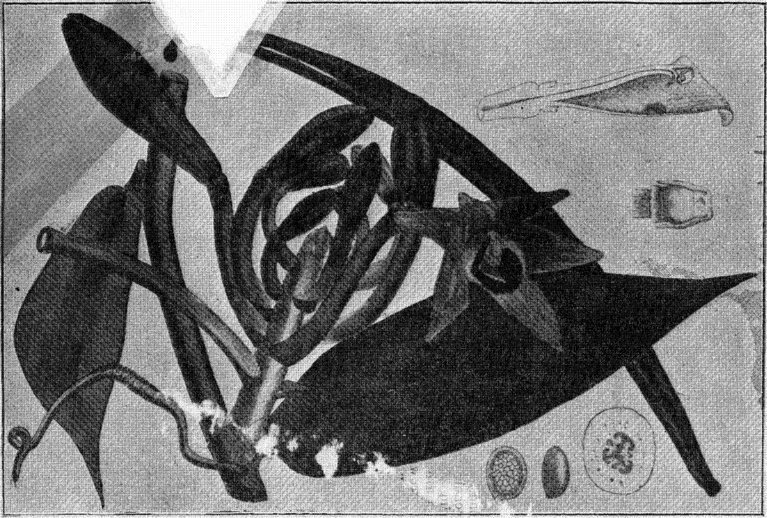

Plate I: Vanilla flower cluster and ripe pod, 5-7 natural size. (After Bentley and Trimen).

MICHIGAN STATE College
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VANILLA CULTIVATION IN HAWAII.

The vanilla bean is the cured fruit of a vine belonging to the orchid family. The term "bean" is a misnomer, as the plant is not a legume. The elongated fruit pods are from five to eight inches long and the size of a lead pencil. They are black, glossy and somewhat wrinkled on the surface and contain thousands of exceedingly minute black seeds.

The vanilla plant is a native of Mexico (Pl. I). In 1808 Andrews gave the name *Vanilla planifolia* to the best varietty, known there as mansa o fina. Today this plant is found wild in the light forests of Southeast Mexico, Peru and on Luzon, Philippine Islands. It is also extensively cultivated in the province of Vera Cruz, Mexico, and on the islands of Reunion, Madagascar, Mauritius, Java, Fiji, Tahiti and the Seychelles. The plant is a fleshy dark-green perennial climber, adhering to trees by its aerial roots. In a vanilla plantation these trees are called supports. The vine attains the thickness of a finger and grows singly for a considerable height. When nipped or bent over a number of shoots are thrown out, which bear flower-clusters, each yielding ten or more flowers. The flowers open about five weeks after they burst through the buds. The pods grow to their full size in five weeks, and mature in about seven months.

Temperature. It may be stated in a general way that the vanilla plant requires a mean temperature of 77° F. and abundant rains during two-thirds or three-fourths of the year. The production is more abundant and of better quality in countries having a distinct dry season. The humidity should be about 75° and the soil always moist. The temperature must not be subject to sudden changes and should not go too high and never below 49° F.

Soil. Any soil is suitable, provided the drainage is good. Light soil and porous subsoil should be given the preference. The best locations are valleys with slight slopes, where a moist atmosphere and protection from strong wind may be obtained. Forest land or land which has been covered with a dense growth of lantana should be selected. The decaying leaves and later the decaying branches and trunks will furnish the necessary humus.

The Plantation. Clear the land by means of brush hooks and cane knives and dig out guava roots. Cut down all large trees not wanted for wind-breaks, and cut up the large branches. Trees having a diameter of less than six inches are left standing. Next lay out the fields and set out additional trees for wind-breaks. It must be well understood that a vanilla plantation needs protection from strong wind. It is not sufficient to protect from prevailing winds only, but the field must be protected in all directions. Trees must not only be planted around a large plantation, but lines of trees should be set at intervals thrugh the fields. The lines for the supports may then be marked by stakes. These lines should be 8 feet apart and the trees planted at intervals of from 6 to 8 feet. Low growing trees which do not shed their bark, should be selected for supports. The following are recommended for Hawaii: *Spondias lutea*, (Hog plum); *Erythrina lithosperma*, (Coral tree); *Crescentia*, (Calabash tree); *Bauhinia tomentosa*, (St. Thomas' tree), together with the small trees which have been left standing, provided they are nearly in line. All others should be cut out unless wanted for wind-breaks or shade.

Choice of cuttings. The method of propagation is by cuttings. The shipment of plants is made during the dry season, when growth has been checked. The plants are pulled up from the ground and the roots are freed from soil. The plants may be wrapped in paper or packed in moss. A part of the plantation should be reserved for a nursery, in which the plants are left to grow vigorously, without exhausting them by fructification. This is the best method to obtain strong cuttings, to prevent the plants from degenerating and to guard against diseases. Only those parts of the plants should be used for cuttings that have short joints, as such cuttings will form most roots on a given length. Cuttings giving the best results are obtained from laterals. The joints are short and the terminal bud continues growing. Cuttings of from 3 to 6 joints may be used. Long cuttings may produce flowers 18 months after planting, while with short cuttings abundant flowers cannot be expected before the third year.

Planting. The best time to set out the cuttings is probably the early autumn, but it may be done at any time of the year. The longer the cutting the more should be put in the ground. One joint when the cutting has three, two when four, and even four or five when long cuttings are used. The leaves should be cut from that part of the cutting put into the ground, care being taken not to injure the aerial roots. Cuttings should be placed horizontally and buried 3 inches deep. The exposed end is fastened so that the aerial roots are close to the bark of the supporting tree. The fastener may be raphia or any other band. No string should be used. Should dry weather follow the planting, it would be advisable to water the plants. In Mexico cuttings 2 feet 6 inches long are made eight days before planting. Some planters use cuttings 3 feet 6 inches long, bury 1 foot 1 inch deep and cover with leaves and grass. Covering is necessary during dry, warm weather to protect the rootlets, which are close to the surface and would be killed by the sun.

Cultivation. The trees used as supports should be pruned in the late fall. Vanilla requires some sunshine, and when growing in shaded places, bears but few flowers and the fruit does not mature so well. In sunny places, however, the vines suffer, because the surface of the support may become so dry and overheated as to destroy the aerial roots. Some cuttings always remain dwarfed. These should be replaced as soon as practicable. The vine is allowed to grow 2 or 3 feet above the forked branches of its support. This upper portion should be carefully separated and hung loosely over the forks of the supporting tree, making pollination and harvesting possible without the use of ladders. Branches from 2 to 4 feet long, inclining downwards, produce the most flowers. To encourage this growth, the vines are pinched off near the end and thus a thick growth, completely covering the branches of the tree, is obtained. The vanilla plant begins to bear during the third year and continues until 7 or 8 years old. When flowering and maturing fruit, the plants should have a dressing of decomposed leaves, grass or banana leaves and trunks. Stable manure should not be used, unless put into trenches, where the roots will reach it when well decomposed.

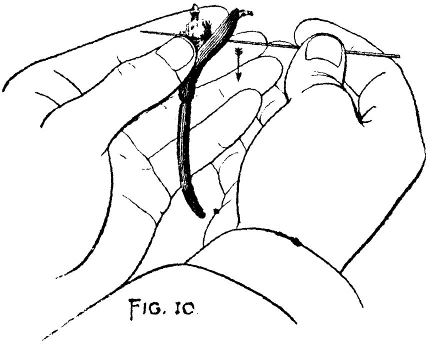

FIG. 10

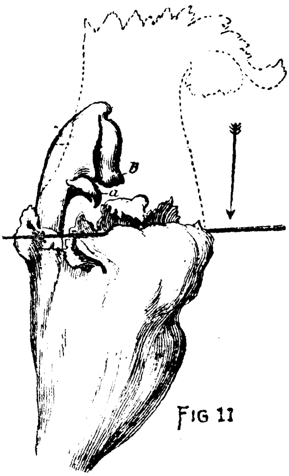

FIG 11

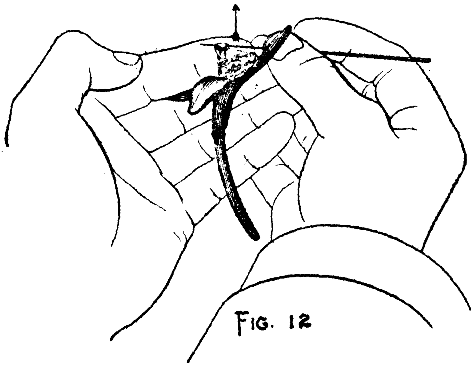

FIG. 12

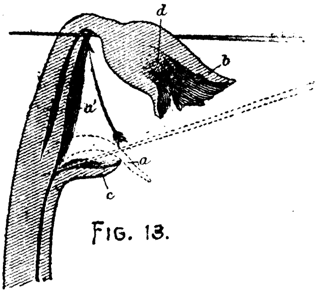

FIG. 13.

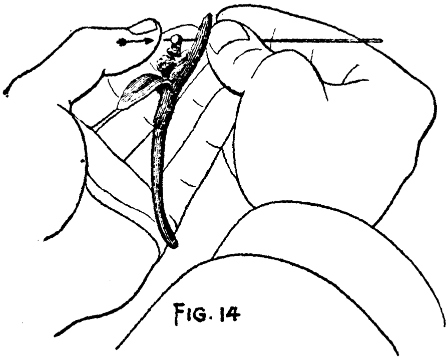

FIG. 14

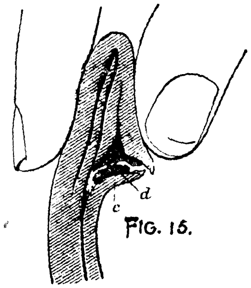

FIG. 15.

Plate II. Method of hand pollinating Vanilla flowers. (After Lecomte).

Pollination. (Pl. II). In Hawaii the flowers do not produce fruit unless fertilized by hand. This must be done the morning they open. One man can operate 1000 flowers from sunrise to 10 or 11 A. M. In case the operation is successful the flower remains attached to its stalk, otherwise it drops off in three days.

"The flower is taken in the left hand, three fingers being placed at its back and the thumb in front, the column with organs of fertilization on top being supported against the middle sepal behind. A bit of hard wood, cut the size of a toothpick and scraped smooth and flat at one end, is the only tool required; this is held in the right hand between the thumb and forefinger. To get at the organs of fertilization easily, the sack which grows from the side of the column enveloping its front and marking the sexual organs is pressed down by the bit of wood, or this is run through its base, and the sack torn up, or the whole sack may be plucked off with finger and thumb, it matters not how it is laid open, so long as this is done quickly and without injury to any other part of the flower. The smooth end of the fecundating instrument is then laid flat on the front of the column, just beneath the organs of fertilization, and being pushed up, (fig. 12), it catches under the flap which keeps the pollen from coming in contact with the stigma. The flap is raised along with the stick till it lies flat against the upper part of the column, (fig. 13), being held in that position by the bit of wood. The stamen, at first raised along with the flap, now falls down again into its original position, and the flap being out of the way, the pollen comes into contact with the stigma, and a slight pressure of the thumb on the stamen lodges the pollen in the position required, (fig. 15); the bit of stick being then quickly but gently withdrawn, the operation is complete."*

Harvesting. The fruit reaches maturity 6 to 8 months after the flowers are pollinated. The pods become hard, thick, turn greenish-yellow, and a slight bruising sound is audible when the ripe pod is pressed between the fingers. To prevent splitting, pods should be gathered the day they ripen. The pod is taken near the stem-end between the thumb and forefinger, twisted from right to left and pressed aside with the thumb. Attached pieces of flower-stalk are later cut away, but breaks or cracks in the pod itself, rank it as inferior in quality. Pods picked before maturity are deficient in perfume and more subject to fungus growth.

The gathered pods are spread out and exposed to the air for 24 hours. During this time they are sorted as follows: 1, ripe and perfect; 2, unripe but perfect; 3, split; 4, spotted, or, having black points or pieces of flower-stalk attached; 5, curved pods. Attached pieces of flower-stalk must be carefully cut away and black points should be removed. The curing should begin when a sufficient quantity of vanilla has accumulated, as otherwise the pods would split or become mouldy.

Vanilla is prepared for the market in various ways. The best results have been obtained in Mexico. All methods have been carefully studied and the results compared at this Station. A modification of the Mexican method is recommended as a result of these investigations. This method is based on scientific principles, is simple in application, requires but a small outlay for buildings and produces a finished article of superior quality.

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* Galbraith, Vanilla Culture; Div. Bot., Bul. 21, U. S. Dept. Agric., 1898, p. 15.

Buildings required. A platform must be constructed. This may be made of stone, coral or cement, should slope slightly towards the south and be protected from the wind by a wall running east and west. This wall should be whitewashed to reflect more heat onto the platform. A drying house must be built. This should be provided with shelves on which the cured vanilla is laid out to dry, also with stands where trays loaded with vanilla may be arranged one above the other. Portable sweatboxes are made of wood. They should be 2 feet deep, 2 feet long and from 16 to 18 inches wide and have a detachable cover. A supply of mats and dark colored woollen blankets must also be provided.

Curing. On a clear warm day, when the platform is dry and warm, mats are spread evenly on the floor of the platform and covered with dark colored blankets. The mats and blankets are previously hung out in the sun. At 9:30 or 10 a. m. the vanilla is spread out quickly and carefully. The first row is started along the wall, the pods laid evenly without touching one another, the stem end farthest from the wall. The pods are left in the sun until thoroughly heated—they should be too warm to be held in the hand. The more quickly the sun heats the fruit and the warmer they get, the better it is. The sweatboxes and dark colored blankets are set out in the sun, and must be warm when the vanilla has reached the proper stage. This should be not later than 2 p. m. The blankets are used as lining and the edges hang over the sides of the box. The heated pods are taken up by handfuls and laid in the boxes, stem end inside, care being taken to put the colored pods at the bottom. The green ones are laid on over these. The box must be filled as quickly as possible, the overhanging blanket edges are covered over the contents and enough warm blankets added on top to competely fill the box. When the cover is securely fastened the box is carried to the drying house and left until the next day. During this time the vanilla turns dark brown and sweats freely. The vanilla remains in the box from 2 p. m. until 10 a. m. The box is then opened, the vanilla examined, spread on the platform and repacked as during the preceding day. This is repeated until sufficiently sweated. This may be accomplished in 4 days, but with unfavorable weather it may require two weeks.

Pods which have remained partly green after the first sweating should be separated, spread out in the sun, the colored parts covered with several thicknesses of white cloth, so as to expose only the green parts to the sun. This is done to cure all parts of the pods equally. Pods which have split during the first sweating are wrapped with thread and the split part covered with white cloth when exposed to the sun.

The sweating having been completed, the vanilla is spread out on trays in single layers. The following days the trays with the vanilla are set out in the sun for a few hours and otherwise dried in the shade. The last drying is done only in the shade, and the trays are covered with cheesecloth to keep off the dust. Fully dried vanilla is packed in tin boxes and coveerd with cloth.

The finished article has a well developed aroma, feels dry but pliable and has a dark brown color. After remaining in the tin boxes for several weeks, the vanilla is classified and put up in bundles. These bundles are packed in tin boxes, which are lined with oiled paper of correct dimensions. One month later these boxes are opened, carefully examined, damaged packages removed, opened and cared for, good packages of the same size substituted, the boxes closed, soldered and labelled.

To provide against loss during rainy weather, the sweating must be accomplished by artificial heat. Good results can be obtained by the use of a bake oven or coffee-drying house. The vanilla is put up in packages of certain size and shape and wrapped in woollen blankets and mats to prevent overheating. The drying can be completed in a heated drying house.

The sorting, curing, drying, classifying and packing must be done by an experienced man. A well equipped central curing establishment with an experienced foreman would, therefore, be very desirable from an economical point of view.

Yield. This has never been properly ascertained in Hawaii. The wild vanilla plant of Mexico bears one, two and rarely five pods, all of superior quality. Two cultivated and hand pollinated plants at Moanalua, Oahu, produced 300 pods in 1902, and 150 pods in 1903, about one-fourth being of good size and quality. This only indicates what may be accomplished by cultivation, but is neither practicable nor advisable on a large plantation. Plants yielding a very heavy crop may become exhausted. The roots, and sometimes the stalk, rots away or the vines turn yellowish green, the leaves become soft and white, the tendrils dry and the whole plant dies. A yield of 10 pods for ordinary and 20 or even 25 pods for strong, healthy plants should be a safe limit. One a basis of 10 pods per plant, 2 plants to each support, and 680 supports per acre, a yield of 13,600 pods would be secured. One thousand average good pods weigh 45 pounds, and dry to half their volume and about one-fifth their weight during the curing process; 13,000 pods weigh 585 pounds, and the finished article about 120 pounds. At least one-half of this should be of superior quality and sell for from $6 to $9 per pound, f. o. b. Honolulu. The balance would bring from $1.25 to $4 per pound. This would give a return of not less than $435 per acre. This, however, can only be accomplished when a fair portion of the finished article is of superior quality.

Diseases. All the vanilla reported to be growing on these islands has been inspected by an expert of this Station and found free from fungus or other diseases, as well as from the various insect pests which affect this plant in other countries. Should any of them make their appearance, planters are requested to at once notify this Station, giving particulars and mailing a specimen of vine affected.

More detailed information in regard to the cultivation, curing and classifying of vanilla will be given in a bulletin which will be issued by this Station whenever the growth of the industry demands it.

FRANK E. CONTER, Assistant.

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Hawaii Agricultural Experiment Station,

HONOLULU.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 10.

THE PINEAPPLE SCALE.[1]

(Diaspis bromeliæ Kerner.*)*

BY D. L. VAN DINE,

Entomologist, Hawaii Experiment Station, United States Department of Agriculture.

This pest of the pineapple is a scale insect, one of the Coccidæ, which, because of its special fondness for this plant, has received the common name the "Pineapple Scale." The insect was first described by Kerner in 1778, and besides attacking the pineapple is widely distributed on various plants in greenhouses. It has been reported from the countries of northern Europe; from Massachusetts, Washington, D. C., Ohio, California, and Florida in the United States; and from Mexico, Jamaica, Cape Colony, and Natal. Prof. V. L. Kellogg of Stanford University, to whom the writer is indebted for the determination of the insect, says: "Probably *bromeliæ* (pineapple scale)

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[1] Second reprint.

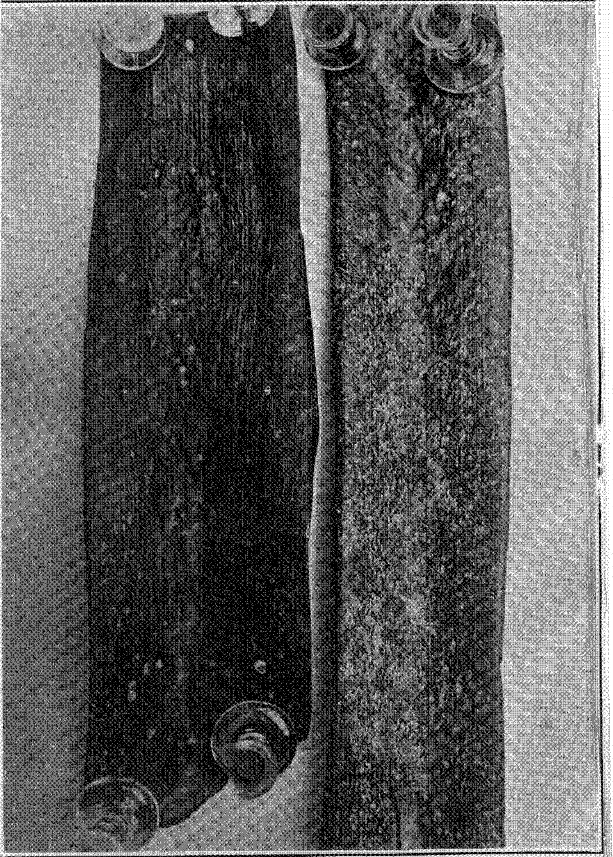

FIG. 1.—The pineapple scale, *Diaspis bromeliæ*. Leaf at right showing male and female (circular) scales. Leaf at left with scales removed showing symptoms of work.

will be found in time wherever the pineapple is grown." Other food plants are ivy, canna, hibiscus, acacia, olea (olive), billbergia, and certain varieties of greenhouse palms. The writer took the first specimens of this scale from a pineapple plantation at Wahiawa, Oahu, on October 26, 1903, and since then has observed the pest in every plantation visited on this island and the Island of Hawaii. Although occurring generally throughout the islands, Mrs. M. E. Fernald[2] does not record it from Hawaii in her catalogue of Coccids, nor is it found in Mr. Kirkaldy's recent work on Hemiptera in Fauna Hawaiiensis. Mr. P. H. Rolfs[3] says regarding the appearance of this insect in Florida: "It has been found repeatedly on plants imported from Hawaii, and has been disseminated to many parts of Florida." Dr. L. Reh[4] of Hamburg, Germany, also records the pest as common in these islands, having collected specimens himself at the government nursery on Feb. 28, 1902.

Prof. F. V. Theobald,[5] an English authority on economic entomology, says: "Pineapples are frequently damaged by a scale insect, which now and then causes the fruit to rot. * * * This scale is the pineapple scale (*Diaspis bromeliæ* Kerner). The scale is thin, circular and pure white—the females yellow or orange. Like most Diaspids, they burrow beneath the epidermis of the plants and become almost entirely hidden. It chiefly attacks the leaves, but now and then the fruit. It should be destroyed as soon as the fruit is cut."

Dr. Reh in describing the work of this scale states that it attaches itself to the plant on the base of the leaf, spreading from there to the stem and eventually covering the entire plant, which it kills. On the fruit it attacks principally the green, unripe portion. A symptom of an attack is rust-colored spots on the leaves. Dr. Reh says further that milk of lime was used as an insecticide for this pest in Berlin and Russia.

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[2] Massachusetts Hatch Sta. Bul. 88.

[3] U. S. Department of Agriculture Farmers' Bulletin No. 140.

[4] Zeitschrift für Entomologie, Jan. 15, 1904, p. 30.

[5] First Report on Economic Zoology. British Museum, London, 1903.

These small, scale-like insects are very conspicuous, because of their color, and not easily mistaken for other forms. The scale and not the insect inself is the object commonly seen. The insect is found beneath this secretion, which serves as a shield. In the case of this insect the scale or protective armor is made up partly of a waxy secretion of the insect and partly of molted skins. The insect itself in the adult stage is quite well buried beneath the epidermis of the plant and hence the necessity of combating the pest in its early stages.

The pineapple scale can be controlled by spraying where it occurs in the field. The cheaper and easier method is by proper preventive measures to keep the pest from gaining a foothold in the plantation. These measures are to burn all leaves where the pest is at all evident after harvesting the crop, to dip young plants in an insecticide before planting, and to produce the maximum vigor and health of the plants by thorough cultivation and fertilization. In the question of the control of the insect pests and diseases of plants, no one point is more important than vigorous and clean cultivation and the proper supply of plant food and moisture. It is an accepted fact in applied entomology that a healthy growing plant is capable of offering resistance to the attack of an insect pest.

Dr. L. O. Howard,[6] entomologist of the U. S. Department of Agriculture, mentions a hymenopterous parasite, *Aspidiotiphagus citrinus* Craw., bred from the pineapple scale at Washington.

The remedies advised by Mr. Rolfs in his Bulletin on Pineapple Growing have been verified in experiments at this station, and on our recommendation have been tried and reported as successful by the managers of two pineapple plantations.

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[6] Insect Life, Vol. VI, p. 231.

REMEDIES.

Kerosene emulsion:

Whale-oil soap (or any hard soap shaved fine)	½ pound.
Water	1 gallon.
Kerosene (coal oil)	2 gallons.

Dissolve the soap in the water while it is boiling over a fire. When the soap is well dissolved, remove the solution a safe distance from the fire and add it to the coal oil. Churn the mixture, using a strong force pump, for a few minutes until it has a creamy consistency. If the emulsion is well made the oil will not rise to the surface on standing. This is the stock solution and will keep for several weeks. When wanted for use dilute one part of the stock solution with ten parts of water. Dip the plants in the emulsion before setting out in the field or apply as a spray to infested plants in the field. When applied as a spray in the field do not treat the plants when the fruit-bud is forming—do the spraying either before the fruit-bud starts to grow or after it is partly grown. Use only enough of the mixture to wet thoroughly the scales. If too much is used it will collect at the base of the leaves or run down about the crown and it is apt to injure the plant.

Resin wash:

Resin	pounds	5
Caustic soda (crude 78 per cent.)	"	1
Fish oil (whale oil soap)	"	½
Water	gallons	20

Full directions for the preparation of resin wash are given in Bulletin 3 of this station.

In using the resin wash follow the directions given for the kerosene emulsion.

The emulsion, being a more permanent mixture, more easily prepared and more active, recommends its use in place of the resin wash; however, the use of either mixture is a point for the planter to determine to his own satisfaction.

The question of ingredients and proper spraying apparatus is a very important one. Failure is in the majority of cases due to poor material or insufficient apparatus. A cheap pump, which soon becomes useless, is always more expensive than a well-made outfit at whatever cost. For field spraying where the ground is rocky and uneven, a compressed-air knapsack sprayer will be found suitable, while on level land, which will permit a wagon passing through the rows, a barrel outfit will be found the more desirable. These are points which only a knowledge of local conditions will permit definite advice being given. Further information will be gladly given. Address Mr. Jared G. Smith, Director, Hawaii Experiment Station, Honolulu, Hawaii.

HONOLULU, *August 11, 1904.*

Hawaii Agricultural Experiment Station,

HONOLULU.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 12.

TOBACCO EXPERIMENTS IN HAMAKUA, HAWAII.

INTRODUCTION.

In the Autumn of 1903, a co-operative experiment was arranged under the joint auspices of the Territorial Board of Commissioners of Agriculture and Forestry and the Hawaii Agricultural Experiment Station, for the purpose of demonstrating the practicability of growing the best grades of cigar tobacco in Hawaii.

An examination of sites was made by Mr. F. E. Conter, a Special Agent, who, in the beginning, had charge of the work. Mr. Conter visited the Puna, Hilo, Hamakua and Kona Districts of the island of Hawaii and finally selected a small tract on the Louisson Brothers' Plantation on the lands of Pohakea, Hamakua. A lease of 2 1-2 acres of the land was secured in the name of the Secretary of Agriculture, Washington, D. C., at the nominal rental of Five Dollars per annum. Special privileges were granted by the owners of the land, who have assisted the enterprise in every way in their power. The land was new and uncultivated, so that a delay of some months ensued before the field could be made ready for planting. The first crop was transplanted to the experimental plots in March and April, 1904.

The experimental tobacco field was located in Hamakua because the physical character of the soil was right to produce a good quality of crop. The Pohakea Homestead lands were suitable, available and convenient. There are other areas in Puna, Kau and Kona on Hawaii and on each of the other Islands of the group, but at the time this experiment was undertaken, the Pohakea tract was selected as the most convenient place in which to carry on field work.

WHERE CAN TOBACCO BE GROWN?

The determinant factors in the production of tobaccos of high grade and fine flavor are:

Soils of the proper physical texture.

A suitable climate.

Selected seed.

Clean cultivation, fertilization and the requisite skill in curing and fermenting the crop to produce a uniform quality of leaf.

TOBACCO SOILS.

The texture of a soil, that is, the ratio between clay, silt, fine and coarse sand, is held to have much to do with the type of the product. Good seed planted on unfavorable soils will not produce good tobacco. The texture governs the water-holding capacity of the soil, and this, in turn, controls, to some extent, the physiological changes within the growing plant; so that, eliminating other factors, the type of crop, which a given soil will produce, can be pre-determined, to some extent, merely by an examination of the soil.

The color of the cured leaf, whether light or dark, its thinness and elasticity, depend, apparently, almost absolutely on soil characteristics and its water-holding capacity.

SOME HAWAIIAN TOBACCO SOILS.

The soil on the Hamakua homesteads and on the Hamakua tract of land adapted to tobacco,—a belt extending from Paauhau to Hakalau at an elevation of from 1000 to 2500 feet—, is a sandy forest loam, very rich in humus and with a high nitrogen content. The color of the soil is a light brown becoming almost black when wet.

ANALYSIS OF POHAKEA SOIL.[1]

PHYSICAL ANALYSIS	Per cent.	CHEMICAL ANALYSIS	Per cent.
Combined water and organic	35.935	Water	19.540
Fine gravel 1.—2. mm.	16.511	Organic and combined water	28.360
Coarse sand 1.—0.5 mm.	11.337	Insoluble	19.320
Medium sand 0.5—0.25 mm.	6.716	Fe_2O_3 Al_2O_3 Iron and alumina	28.797
Fine sand 0.25—0.1 mm.	14.002	CaO..lime	.300
Very fine sand 0.1—0.05 mm.	8.339	Mg. O magnesia	.631
Silt 0.05—0.005 mm.	5.848	SO_3 sulph. acid	.343
Clay 0.005—0.0001 "	.940	P_2O_5 phosphoric acid	.703
		K_2O potash	.077
		Nitrogen total	.728
		Humus "	12.470
		Humic nitrogen	.560
		Nitrogen % in humus	4.490

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[1] Analysis by Dr. Edmund C. Shorey.

It will be noted that although the "iron and alumina" content is high the percentage of clay is very low. The "fine gravel" and "coarse sand" are really reducable to "fine sand" and "very fine sand" if the soil is shaken in water for longer than the customary period previous to analysis. There is almost no true clay in this soil, and practically no true gravel or coarse sand.

The lime is present as a silicate and is too low in quantity to neutralize the acidity. The potash content is very low. Nevertheless a dressing of sulphate of potash applied to the experimental plots at the rate of 500 pounds per acre produced cigar leaf of exceptionally good burning qualities. The nitrogen although high is largely unavailable so that it will pay to use moderate amounts of nitrate on the crop. The phosphoric acid is presumably largely unavailable.

ANALYSIS OF KONA SOIL.

A tobacco soil above Kailua at an elevation of 600 feet compares very favorably with some of the best Sumatra soil:

Kailua, Kona Soil.[1]	Per cent.	Rimboen, Sumatra soil.[2]	Per cent.
Organic and combined water	30.82	Organic matter	23.41
Fine gravel	11.85	Gravel	.81
Coarse sand	13.25	Coarse sand	1.44
Medium sand	3.95	Medium sand	3.62
Fine sand	8.42	Fine sand	13.94
Very fine sand	28.25	Very fine sand	19.52
Silt	1.75	Silt	23.51
Clay	.85	Clay	2.72
Total nitrogen	.94		
Color of soil, light brown.			

[1] Analysis by Dr. Edmund C. Shorey.

[2] Bul. 5. Div Soils. U. S. Dept. Agric., Washington, D. C., 1896.

Hawaiian soils on cultivation rapidly disintegrate their coarser particles. The shotty particles technically classed as "fine gravel" and "coarse sand" when worked with a rubber pestle or rubbed between the fingers crush down to a fine powder. The ultimate soil grains are agglutinated in masses because of the exceptionally large percentage of organic matter in the soil.

The Kona district is undoubtedly better adapted to tobacco cultivation than Hamakua because of the protection from strong trade winds. But the tobacco soils of Hamakua and Kona are very similar in all their characteristics.

CLIMATE.

The influence of climate on the growing of tobacco is a potent factor. Cigar tobaccos, of good quality, are produced through a wide range in latitude. Proximity to the ocean has always been considered a deterrent influence.

Tobacco requires from 70 to 100 inches annual rainfall, from one-half to one-third of this during the growing season. Moderate temperatures, frequent showers or irrigation, to promote even, uninterrupted growth, neither too rapid nor too slow, constitute an important element in determining the suitability of any district where soil sonditions are correct. Monotony of daily and seasonal temperatures are characteristic of Hawaii, so that the rainfall or the ability to irrigate the crop, when required, become of greater importance than any consideration of actual temperatures.

In the windward districts, protection from wind must be provided. This may be accomplished either by tenting the field with cotton cloth, as in Connecticut and Florida, or, permitting the larger ohia trees to remain when the land is cleared; or, in case tobacco is planted on lands cleared for cane or other "open-field" crops, by planting or constructing suitable windbreaks. In the leeward districts, the protection from wind may be neglected.

THE INFLUENCE OF GOOD SEED.

The necessity of procuring the best seed is a factor not to be neglected or minimized. The final test, as to the value of a crop of tobacco, does not come for at least a year after the seed is sown, and, in the case of the finer cigar wrapper and filler types, not for two or three years. Each year, more and more attention is being given to the selection of good seed. Tobacco seeds are extremely minute. An ounce, if every seed were good, would produce plants enough to plant several acres. It will be absolutely necessary for planters in Hawaii to save their own seed from the best individual plants of the best strains to the end, that a race of tobacco, adapted to local conditions, may be developed.

CULTIVATION AND FERTILIZERS.

Tobacco is a crop that re-pays the planter in proportion to the ratio of cultivation and attention that he gives it. It is not a crop that can be left to care for itself. Constant and painstaking supervision of every detail toward the making of the crop will well repay the cultivator. Tobacco is essentially a hoed crop. Weeds are plants growing out of place. Any plant, except tobacco, in a tobacco field is a weed and must be kept down. Cultivation and fertilizers must be used and applied for the purpose of maintaining an even, rapid growth, for there is no doubt that uniform rapidity of growth has its influence on the quality of the finished product. Light applications of nitrate of soda, at intervals during the growth of the plant, will do much to promote this required uniformity.

The curing of the ripe leaf and the fermentation of the cured article, are comparatively recent developments in the science of tobacco culture. These processes were formerly carried on by rule of thumb and the reasons for curing or fermenting were but little understood. It is now, however, generally recognized that curing and fermentation are controllable processes, which, when properly conducted, tend towards improvement of the quality and value of the finished article, the marketable tobacco.

If we are to produce tobacco on a commercial scale in Hawaii, the rules of experience which have been developed in Cuba, Sumatra or other tobacco-growing lands, must be modified and adapted to our own peculiar local soils, climate and conditions.

This Report is and can be only preliminary. The results of one year's experimenting indicate that we can grow fine cigar-leaf tobaccos of the Havana type, which can be classed in flavor, texture, aroma and burning qualities with the medium grades of tobacco imported from Cuba. Our volcanic soils are not comparable with the sandy soils of Florida or the limestone soils of Cuba, and yet, the fact remains that we have produced good tobacco and can probably do much better during the coming seasons, as a result of more experience and better equipment.

After comparison of our results with those obtained elsewhere in growing tobacco of fine quality, it is believed that uniformity of temperatures, with sufficient moisture during the growing season of the plant, have as much to do with the quality of tobacco as any other physical or climatic factor. If this be true, our remarkable monotony of temperatures and narrow variations, daily, monthly and seasonal, should make it possible to grow in Hawaii fine tobaccos which will, in time, be classed as distinct from those of any other land.

In the beginning, the market for Hawaiian grown tobaccos will be at home. It will be better in the beginning to develop and cater to the local demand.

SEED AND SEEDLINGS.

One of the main items for success in tobacco culture, is to have good, strong, healthy plants ready to transplant to the field at the proper time. Good *seed* is the first essential in their production, for without good stock to start with, one can hardly expect to obtain the best results. How to produce that kind of a plant is still question, whether by using a rich soil in seed boxes or beds and procure a rapid growth of top upon a slender root, or, to use a poorer soil and develop more root growth and less leaf, depending upon the stronger root to give the plant a better start when set out in the field. It would appear that the stronger the root system, the better will be the results when the seedlings are transplanted.

An open seed-bed, as is used in other countries, would prove a failure in Hawaii. Insects are too numerous and the soil too full of humus to stand burning.

Two methods can be recommended. The first of these is *elevated* boxes, set about 20 inches from the ground on posts, the box level and projecting at least 6 inches outside the posts, 3 1-2 to 4 feet wide, 10 to 12 feet long and at least 6 inches deep. Fill full with good soil, sifted to remove sticks, trash and stones, the last inch being finer, so that the seed, which is very small, may come in closer contact with the soil but not be covered too deeply. Add a pound or two of air-slaked lime and mix well with the last 2 inches of top soil filled into the boxes or beds.

Good soil can always be distinguished by its texture. If it is soft, moist, not too cold and has a velvety feel, it is good, whereas, a coarse, hard, dry soil, feeling like small peas or pebbles, will not hold moisture, it being too open and porous. Soil rich in humus is sour and, in it, plants do not do well on this account. The lime added to the top soil in the seed-bed corrects this acidity. It is often a good plan to water the seed-bed with lime water, even after the plants are up, but the best is to mix the lime in the top soil.

The seed-boxes, when the seeds show up, should be covered with a gable-roofed frame, covered with cheese cloth or light, open cotton. This cover retains the moisture, maintains a more nearly uniform temperature, and wards off insects.

The other method is to build a large cloth house, with gable roof and in it, arrange the beds so as to get around among them, The elevated boxes, for a few plants, are the easiest to make and care for. In an excessively rainy period, the boxes do not drain off the water as well as the beds and become cold and soggy. For growing a large number of plants, the seed house is to be preferred.

All seed boxes and beds should be sterilized, especially to kill insects and their eggs. An easy way to do this is to use from 10 to 20 gallons of boiling water, applied as evenly and quickly as possible and cover with some kind of a blanket to retain the heat. A pair of saddle blankets answer the purpose nicely.

After the seed-beds become cold, they are ready for the seed, and if the top has become packed, it should be loosened and made fine.

Tobacco seed is exceedingly small, an ounce containing about 380,000 seeds, of which, at best, only about 50 per cent. will germinate. One pod produces fully 5000 seeds and one plant is capable of furnishing seed enough to plant 250 acres, if all were to grow. One heaping tablespoonful of seed will sow 100 square yards of seed-bed and furnish plants to set from 4 to 5 acres, with 10,000 plants per acre, of cigar tobacco. Mix the right quantity of seed with a quart or so of dry, sifted ashes. The ashes show where the seed has or has not been sown on the surface of the bed.

The seed-box or bed, after sowing, should be watered, using a fine rose watering-pot, so as to moisten the soil and also to pack it around the seed, but only enough water should be used to give the desired result.

Cover the seed-boxes or beds with open burlap (old grain bags, cut open, do well for this purpose), until the young plants appear, then the boxes are ready for their movable gable-roofed covers. All covers for plants, after they are up, should be so constructed that the roof partially turns the water, or else it drips through in large drops, which soon kill the tender leaves of the plant by pounding them against the ground. All flat covers should be avoided, for the same reason, unless the cover comes in direct contact with the surface of the ground and, even then, a very heavy rain makes a crust on the top of the soil.

Tobacco seed should be sown thinly, so the plants have room to grow; each plant should have at least one square inch of surface to make a sturdy plant. Seed-beds should, at all times, be fairly moist and never be allowed to become dry or to show dryness on the surface. The seed is small and is only planted on the surface. Good seed should germinate in from 12 to 15 days. In from six to eight weeks, the more hardy plants will be ready for the field and the others will follow in quick succession, until the bed is exhausted of all desirable plants.

Young plants should be allowed considerable sunshine to harden them before transplanting.

Every tobacco grower should save his own seed, and, in its selection, care should be taken to save seed only from such plants as fill all the requirements that are exacted by the trade in the finished leaf.

In a field of growing tobacco, many types may be observed. The best should be selected for seed. By protecting the seed heads or keeping all other plants well topped, cross fertilization may be avoided.

Seed plants should have the small upper leaves and all the sprouting seed branches and suckers removed and seed only saved from the center head. All the large leaves should remain on the plant until seed is mature, when the pod turns brown in color.

PLOWING AND TRANSPLANTING.

The land selected for a tobacco field should be such as can be plowed both ways. It should be sheltered from the high trade winds that sometimes blow with great force. Small square plots, of from 2 to 5 acres each, would form good fields for a small planter, especially if surrounded by the forest. It is well to plow the land some little time in advance of the planting.

Tobacco being a tap-rooted plant, in some instances sending its roots down to a depth of 2 feet or more, requires that tillage shall be deep in preparing the land to receive the young plants. The soil should be plowed to a depth of at least 12 inches. The work must be done in such a manner that the sub-soil is not brought to the surface. Have the soil fine and loose but leave the sterile, acid sub-soil underneath where nature placed it. Put the soil in good, mellow condition, as it pays to do so for any crop.

As soon as the land is plowed and harrowed, the field should be poisoned to kill pokos, army worms, Japanese beetles and the various pests usually abundant in newly turned land. There are two remedies which are of about equal value. Sow one or the other of the following broadcast over the newly plowed land:

Arsenicated Horse-manure. To 40 pounds of dried, fresh horse manure, as free from straw as possible, add 6 to 8 ounces Paris Green mixed with 5 pounds of common salt. Stir until the salt and Paris Green are thoroughly incorporated in every part of the manure. This amount is sufficient for one acre.

Poisoned bran. To 2 pecks of bran or coarse cornmeal, add 4 ounces Paris Green or 8 ounces disparene and 2 quarts of molasses or honey or 5 pounds coarse sugar. If sugar is used, moisten the bran with water. Stir and mix thoroughly and scatter over the field.

Poisoned horse-manure is safer than poisoned bran and somewhat cheaper. Pokos and army worms like it fully as well as the sweetened bran and cattle, chickens and other domestic animals are less liable to be poisoned through eating it. The Japanese beetle seems to prefer the poisoned bran.

The field being prepared and the plants ready, they can be set out at any time of the year when the soil is in a moist condition and the sky is clouded. Plant only good, strong, healthy plants in the field. It is poor economy to set a sickly plant anywhere and give it care and cultivation, with but little chance for a return from it for the time and labor expended.

It can hardly be expected, and especially in Hawaii, that every seed will grow and produce an ideal plant. Such has not been our experience. It seems to be a characteristic of tropical countries, and, to this Hawaii is no exception, that cultivated plants show marked individual variation in their growth. Some plants, even of types that show unformity when grown in cooler lands, when grown in hot countries break up into a number of forms. There must be enough good plants to reset in the places of those that fail to grow or vary from the type.

The tap-root of a tobacco plant is its anchor. In planting, it should be kept as straight as possible. The growth and success of the plant depends upon this being carefully looked after. Our experience has been that eight out of ten plants that failed to make a good growth could be traced to a deformed tap-root or careless transplanting.

In taking up young plants from seed-beds or boxes, use a pointed stick to run under the plants wanted, and, with a prying and twisting motion, this plant is so loosened that, taking it by the tips of the top leaves, it can be lifted from the soil with most of its roots intact. Do not take hold of a small plant at the growing bud, for it will be bruised, no matter how lightly handled. If the plants are large, they may be handled at the base of the stalk far better than by the leaves when planting out in the field.

Pack the plants carefully in a broad, shallow basket or tray, provided with a handle and keep covered from the air and the sun. If the field is near, do not lift too many at one time. Do not place any of the plants in water, as it causes all lateral roots to cling to the tap-root, from which they can not easily be separated, thus causing the plant to be poorly set. A little loose, damp earth, sprinkled among the roots of the plants and the tops slightly wet and covered, prepares the plants to stand a longer journey. Properly packed, they can be set next day with good results or can be transported to some distance. It often saves time to set a few extra plants now and then through the field, between the regular rows, to be used later to fill vacancies that may occur. Quite large plants can be moved if a little soil is left around the roots.

Sometimes it is advisable to set small plants from seed-beds or boxes to a nursery until they attain a larger growth, if not enough seed boxes or beds have been provided. Another good reason for doing this is that after a good many plants are removed, the remainder are loosened and disturbed.

If the sun is shining when the seedlings are transplanted, the young plants need some shade until they start. Ti leaves make a good shade. Stick the stem end into the ground and bend it over the young tobacco plant and fasten the other end with a handful of soil laid upon it.

Take the plants from the seed-beds with all the roots possible. Do not pull them up and break the lateral roots, but loosen the soil well and take up carefully. If the tap-root is too long, pinch it off some, but be sure to plant it straight. Set the plants well into the ground. Set large plants with the hand and have the soil so loosened up that the end of the fingers do not come in contact with the *hard sub-soil* in scooping out a place to set the plant, then holding the plant in the center of the hole thus made, supporting any lateral roots with the fingers, firm the bottom of the tap-root with soil up to the lateral roots, then spread these out and place fine soil upon them, fill up and firm the top with the hands or with the feet.

In Hamakua, tobacco can be set at any time and will grow, but it will grow better and faster from February to September (warm weather), although, if set in September and October, if the ground is wet, it will make enough growth to mature a crop during the cold weather.

It pays to take considerable pains to get good stocky plants and have them well set. A full stand of seedlings of uniform age and vitality is the first requisite towards success in growing tobacco.

If the acreage is large enough to warrant the outlay, transplanting machinery may be employed. With three men and a good team, from two to four acres of tobacco can be transplanted in one day. These machines set the plant, water it and pack the dirt around it, and, when running in proper shape, do the work more uniformly than a gang of laborers.

Young plants can also be set with a flat, round-pointed dibble. This instrument leaves a deep, narrow opening in the soil, allowing room for the lateral roots to stand out straight and the earth is firmed up against the plant. The roots are then in a good position and not cramped up in a small, round hole. If water is used during planting, the hole left by the dibble in firming the plant, is the proper place to apply the water.

Care should always be used in handling young tobacco plants, as the leaves and shoots are very brittle and tender and break easily. Tobacco should be planted on slightly raised ridges, some 3 or 4 inches higher than the surrounding ground, as it facilitates drainage, places the plants in a more decided position and less liable to injury through cultivation.

The distance between the plants in the row and the width of the rows is governed by the kind of tobacco planted and the use to which the finished leaf is to be put, whether wrapper or filler.

Planted close in the row and the rows near each other, the tobacco grows tall, with short, narrow, thin leaves, of a poor body, because they do not get enough sunshine to properly ripen. On the other hand, plants set far apart in the row and a greater distance between the rows, giving more room for the plant to expand, produce the other extreme, a long, wide, thick leaf of heavy body, coarse veins and a woodiness in the cured leaf that is undesirable.

No cigar tobacco should be set less than 15 inches apart in the row, and not less than 3 feet between the rows. Room to cultivate must be left so that the laborers will not break and tear the leaves when working between the rows. But the right distance to plant must be determined by each planter to suit the type of tobacco grown and the character of the soil.

In Hamakua, the average cigar tobaccos, such as the Cuban, Sumatra, Connecticut seed leaf and Zimmer Spanish, do well 15 inches in the row and 3 feet 5 inches between rows. An acre, set at this distance, contains about 10,000 plants.

The manufacturing tobaccos producing a larger leaf require more room each way and should be set 2 feet 4 inches apart in rows 4 feet apart.

The tap-root of a good tobacco plant will go down over 2 feet and its laterals run 2 and 3 feet each side of the stalk.

The lateral or feeding roots run just under the surface of the ground so that cultivation must not be deep enough to disturb them, therefore the more need of a clean field at the start. A clean field is much easier to take care of than a weedy one. A garden rake, lightly run over the surface of the ground, disturbs the crust formed by rain, stopping evaporation and killing sprouting weed seeds. The field is only occupied by the tobacco 3 to 4 months for each crop and should be kept clean for that time. Plants show their appreciation of good care and it pays to attend to their wants.

Having no frosts in Hawaii, throughout the belt of land that can be planted to tobacco, any backward plant can be left to come to maturity and its leaf finally secured, but such plants must not be allowed to flower or produce seed.

TOPPING AND SUCKERING.

In about seven to eight weeks after setting in the field, the plant will send up a head or seed cluster, which should be removed in all cases before any of the flowers open.

Topping must not be neglected, as the pollen and falling petals adhere to the green, gummy leaves, causing them to spot in this climate and become worthless.

Sometimes before topping, but generally after, suckers will start from where the leaf joins the stalk. These must be removed, because they take nutriment from the plant that should go to the leaves, it being leaf development that is wanted.

After the main crop is harvested, a sucker crop may be raised. It is doubtful if it will pay in Hawaii, as it is a difficult matter to get the sucker to grow from the bottom part of the plant, but if all the upper suckers are kept off, a bottom sucker will usually start. After all the leaves on the plant are harvested, the stalk should be cut just above the sucker. If this sucker is not allowed to grow before the plant is cut down, it will not start in this climate, the old plant dying down into the root.

In topping, sometimes a backward plant may be made to increase its yield of leaf from 10 to 20 per cent., if topped a little lower than usual and a sucker allowed to grow from the top of the plant and that, in turn, topped and suckered like the original plant. In topping, cut below the third leaf from the seed bud.

HARVESTING AND CURING.

Between the time of planting and harvesting, a tobacco barn must be provided large enough to care for the entire crop. This structure should be of lumber rather than galvanized iron, with shingle roof, hinged frieze, or gable-ventilators and the sides provided with vertical ventilators extending from sill to plate the idea being to secure complete control of temperature and air draughts within the building during the curing process. The side walls should be of 1"x12" N. W., with the cracks battened. Windows are not required, as the ventilators may be opened for light during the process of filling the barn with green leaf. The inside arrangement should be such that the tobacco leaves, fastened on four foot laths, can be hung in tiers from top to bottom of the shed, so as to fill the whole space. The larger the barn, the more readily can the air temperature within it be controlled. A tobacco barn, properly constructed, should last for twenty years. In Hamakua, at the elevation where our tobacco experiment is being conducted, a stove must be provided to heat the air and control moisture, because of the frequent periods of fog and cloudy weather. This stove is placed outside of the shed with the pipe or flue passing either across through the house, from side to side, or, inside a large barn, around two or more walls.

In from 3 to 4 weeks after topping, some of the leaves will be ripe. The lower ones ripen first and if not removed, they wither, turn yellow, dry up at the point, get spotted in patches and then fall off, a total loss of leaf, as the tobacco is then fit for nothing.

There are two methods in use in harvesting tobacco. For high grade cigar leaf, priming is the one to employ. Each leaf is cut from the plant as it ripens, and, as three or four leaves are ripe at about the same time, it is not so much work as one would think.

The primed leaves are placed in shallow trays or baskets and taken to the curing house. The leaves should be carefully handled to avoid bruising and breaking. It is a great saving of room in the curing house, if at this time, the leaves are assorted according to length.

Tobacco does not cure well if strung, say a 20 inch leaf that is 12 inches wide next to a 12 inch leaf that is 6 inches wide. The wide, long leaf will, in curing, roll over the small one and cover it, so it does not dry properly, but has every chance to mold and also cause the outside leaf to mold.

Room is also gained in the house, as the racks can be so placed to accommodate the different lengths without waste of space. It does not require 24 inches of space in which to hang a 12 inch leaf.

Assorting is more quickly done in the green state, as far as length and width are concerned, than when the tobacco is cured.

In curing, the leaves shrink one inch in every twelve inches of length and in the same proportion for the width. The green leaves, sorted to length, are strung with a sail needle upon cotton twine, face to face, and back to back, about one inch apart. The string is knotted at each end and the ends are slipped into a cut in each end of a 4 foot lath. The laths are then carried and hung in tiers upon the racks within the barn.

Patented tobacco poles, consisting of laths with sharp-pointed 12 inch wires, fixed six inches apart and extending half their length on each side of the lath, are much used in some mainland tobacco districts. The green leaves are strung through their stems on these wires, 4 to 6 leaves on each end of the wire. The leaves should not touch each other. As they wilt, the poles may be shoved along closer together, thus greatly economizing space.

As soon as the house is filled with green leaf, close all the ventilators, and, if the weather is rainy or foggy, apply a gentle heat. If hot and dry, the artificial heat is not required. No exact rule of procedure can be laid down, but the temperature and ventilation in the curing barn must be so regulated as to cause a gradual yellowing of the leaf. The more this process of gradual death of the living cells of the leaf can be prolonged, without inducing the development of molds, rot and pole burn, the better will be the quality of the finished article. Sudden changes of temperature are injurious to the leaf.

All living green plants contain within their cells various unstable chemical compounds known as "enzymes." The physiological function of these "enzymes" is but little understood, but it is known that they increase in amount when the vitality of the plant is weakened by disease. The function of the leaves of plants is to elaborate food to the end that the plants may complete their full life-cycle, put forth flowers and ripen seeds to reproduce the species.

In the artificial cultivation of tobacco, the natural life-cycle of the plant is disturbed and interfered with through continuous topping and suckering or pinching off of all flower buds. This causes what might be called a diseased condition in the leaves. Instead of being able to live as millions of generations of tobacco plants have lived before man took to cultivating this crop, the plant is forced, whenever it gets ready to flower and reproduce itself, to turn back and again store up the necessary supplies of food in the leaves, always having seed production as the ultimate object. In this artificially diseased state, the enzymes within the living cells increase enormously and this is what primarily constitutes the "ripening process" of tobacco leaves. A plant cell, which is being gradually murdered, acquires a comparatively large stock of enzymes. On the contrary, where death is rapid there is but little development of these compounds. It is through the oxidation and chemical breaking down of these enzymes that the curing of a ripe tobacco leaf is effected. In a green leaf that is cut or broken from its mother-plant, the enzymes present are rendered inert if it is quickly dried so that death of the plant cells is rapid. The heat, light and humidity in a tobacco barn must be controlled and manipulated so as to cause the death of the green cells of the leaf by gradual starvation. As the green color fades out of a properly cured leaf, it is succeeded by the characteristic rich, mellow, tobacco brown. When the veins and midrib of the leaf have lost their green color, the tobacco is cured. In Hamakua, the curing process requires from two to four weeks.

The determination of the proper time to harvest tobacco leaves is a matter of judgment and experience. Leaves that are underripe cure greenish, thin, papery and brittle. Those over-ripe become harsh, thick and of uneven color. A ripe leaf cures gummy, pliable, elastic and of an even color.

Each kind of tobacco has its special characteristics and must be treated accordingly. Cigar tobaccos require slower barn curing and more careful manipulation during the whole period of growth, curing and fermentation than do the cheaper grades of manufacturing and export tobaccos.

FERMENTATION.

The fermentation or bulking house should be constructed of T and G or other matched lumber or of 1"x12" N. W., battened, in order to have the room where the fermenting is done air-tight.

Controllable frieze ventilators and windows must be provided. The sills should rest on or in the ground, leaving a dirt floor.

As soon as the tobacco in the barn is cured and has been tied into hands, an operation that must be made while the tobacco is moist and pliable, the hands are packed in cases and taken at once to the fermenting house. The tobacco, when cured, must not be handled when it is dry, else it will crumble and be broken, thus destroying the value of such leaves as are suitable for wrapper.

In the fermenting house, platforms raised about 6 inches from the floor, 12 feet long by 5 feet wide and with boarded ends 7 feet high, have been built. The bottom and ends of the platform are lined with heavy paper.

The hands of tobacco, fresh from the curing house, are placed side by side, butt out, even with the edge of the platform, tip towards center. Another row is then laid, overlapping, tip towards center and so on until the floor of the platform is covered. Layers are built on top of this in the same manner until the pile is from 5 to 7 feet high. A cotton blanket is spread over the pile and this covered with rubber blankets or tarpaulins.

If the tobacco is sufficiently moist and pliable when placed in bulk, fermentation begins at once. A platform, 5x12 feet, will accommodate 5000 to 6000 pounds of leaf. A more satisfactory ferment will be secured using this quantity than with a smaller amount.

The leaves should have from 25 to 30% of moisture when placed in bulk. If too dry, the amount can be increased by wetting down the floor and walls of the house with hot water, or, by leading live steam into the room during the time that the bulk is being filled, as cured tobacco leaves very readily absorb moisture from the air. After the bulk is finished, the temperature of the room should be kept rather high, the ventilators being occasionally opened to permit escape of the ammonia which is generated in volume. If the tobacco was sufficiently moist, there will be a daily rise in temperature or from 5° to 8° F.

"In large establishments the temperature and humidity of the room can be thoroughly regulated to secure uniform progress of the fermentation. This is done by steam pipes to warm the room, in which there are vents for the escape of steam when it is desired to make the atmosphere more moist. The temperature of the room is kept quite high, and the vapor from the bulk which is being worked over is very pun-

gent and almost overpowering. There is a very strong odor of ammonia, which makes it difficult to breathe.

The bulk is watched very closely, and as the temperature rises it is torn down, each hand of tobacco is taken up and shaken thoroughly to dry it a little, to cool it slightly, and to open the leaves so that they will not stick together. Before the sweat is completed the bulk is pulled down and built up eight or ten times, according to the condition of the tobacco. It is impossible, even for an expert curer, to give explicit directions as to when the bulk should be turned, as it depends entirely upon the condition of the tobacco and the temperature it attains, and these must be determined by the operator.

The temperature must rise gradually, and if it is found to be rising too rapidly the bulk is torn down and a fresh one built up. Sometimes the bulk is not up over twenty-four hours before it is torn down again and built up afresh. If the tobacco is in high case—that is, quite moist—the bulks have to be turned over frequently in order to prevent too rapid action and to shake out the leaves which would otherwise stick together. If a bulk, as seldom happens, should dry out, it is turned over and mixed with a bulk which is in high case. The tobacco should never be sprinkled in this stage of the process to bring it into case.

The temperature of the pile is allowed to rise gradually until it occasionally reaches 140° F. The fermentation is then at its highest. From this point the temperature subsides until the fermentation is complete and the bulk attains the normal temperature of the room. This maximum temperature must not be reached too quickly, and it must be managed differently with the different tobaccos. The fermentation must be carefully controlled and not allowed to go too far with the wrapper leaf. With the filler, the further it goes and the more intense the action the stronger and finer will the tobacco be for its purpose, if the work is judiciously done. As a matter of fact, it is not unusual to resweat the filler leaf to bring out the strong, rich properties which it is desired to develop. As the fermentation does not extend to the bottom of the pile, it is customary to put 8 or 10 inches of trash, which has already been sweated, on the bottom.

After the sweat the tobacco is brought into proper case and is then very carefully sorted. The wrapper leaf is sorted into four grades of light wrappers and four grades of dark wrappes, according to the length of the leaves. These are placed in small boxes on either side of the operator, and when a box is full the leaves are taken out and the Cuban tobacco is put up into "carottes" (cylindrical rolls). The carottes are made up into bales similar in every way to the Cuban package, the wrappings being imported from Cuba for the purpose.

The filler leaves are frequently resweated and are usually petuned, a process which makes them very much heavier, darker, and stronger. The petuning is either done by spraying, which is the best way, or by dipping the tobacco. The essential part of the petuning liquid is a thick infusion of tobacco stems of the finest quality obtainable. To this is added molasses, cider, Jamaica rum, or sour wine. Frequently other matters are put into the petuning liquid, according to the taste or fancy of the operator, to add quality to the leaf. This is a secret of the Cuban method, and the only part of the process which they are unwilling to divulge.

When the petuning is done by dipping the tobacco, each hand is dipped separately and is then thoroughly shaken, after which it must be bulked down to draw—that is, until the moisture has become thoroughly absorbed and evenly distributed through the leaves. Otherwise they would be apt to spot and change color. The wrappers are never treated in this way, as it is not desirable that they should have the properties of a good filler.

After the bales have been made up they are put into a warehouse in piles, not over three or four bales high, and should be kept at a moderately uniform and rather cool temperature at least two years, in order that the tobacco shall age, before it is suitable for making up into cigars. There seems to be no particular change that goes on, at least no noticeable outward change, as in the case of fermentation, but the tobacco loses the harshness that is always noticeable in fresh tobacco and becomes mellow, as wines and liquors do by standing. When properly put up it will keep almost indefinitely in the bale, and the longer it is left to age the better it becomes.

There is no doubt that tobacco can be handled much better, as well as more economically, in large than in small quantities. The fermentation is much more uniform in large bulks than in small. If there are several bulks they can, if necessary, be mixed to insure the proper conditions. The different kinds of tobacco need to be treated differently, and this is only possible in case of a large quantity, where the selections will amount to enough to handle. With a large quantity of tobacco, also, it is possible to grade more carefully and more closely, and lastly, it is always essential to have a large supply of tobacco of uniform quality in order that manufacturers may maintain any particular line of goods they may desire. For these reasons the farmers usually sell their crops from the field or from the barn to the larger producers or companies who maintain curing houses."[1]

In Hawaii, the period of fermentation lasts 60 to 90 days. Five pounds of green leaf produce about one pound of finished tobacco.

THE TOBACCO FARM IN HAMAKUA.

The crop planted during March and April, 1904, was the first systematic and scientific attempt to grow tobacco in Hawaii.

An acre was covered with an open wove cotton cloth, "Ariel Tenting Cloth," put upon plates and posts, forming a flat roof about 9 feet above the ground; the sides were also covered with the same kind of cloth, making a tight enclosure.

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[1] U. S. Dept. Agric. Farmers Bul. No. 60, second revised edition; Washington, D. C., 1902, sent free on application to the Secretary of Agriculture.

This covered plot, with some land adjoining, about one and one-fourth acres in all, was planted as follows:

Sumatra, Florida	71.13	per	cent
" Long Stem	2.34	"	"
Cuban, Florida	11.73	"	"
" Vuelta Abajo	2.84	"	"
Connecticut Broad Leaf	2.77	"	"
" Seed	2.05	"	"
Zimmer Spanish	2.98	"	"
Virginia Dark Leaf	.64	"	"
White Burley	3.20	"	"
Japanese	.32	"	"
	100.00		

A good many plants under the cloth shelter were killed by the drip from the seams, wires and plates of the structure. This first year's work demonstrated quite clearly that tenting tobacco is not a success in Hawaii, at least in regions of high rainfall.

The following field notes may prove of interest and value:

Plot A. Sumatra.

One thousand plants produced 19,309 leaves, weighing green, 684 pounds or 137 pounds of finished tobacco.

2,230	leaves,	less than	12	inches	long,	weighed	41	lbs.	13	oz.
1,711	"	"	12	"	"	"	43	"		"
1,900	"	"	13	"	"	"	54	"	9	"
2,209	"	"	14	"	"	"	72	"	6	"
2,152	"	"	16	"	"	"	80	"	6	"
2,283	"	"	16	"	"	"	95	"	5	"
1,895	leaves,		17	inches	long,	weighed	91	lbs.	3	oz.
1,578	"		18	"	"	"	84	"	4	"
1,015	"		19	"	"	"	58	"	12	"
605	"		20	"	"	"	42	"	7	"
243	"		21	"	"	"	15	"	8	"
178	"		22	"	"	"	4	"	7	"
38	"		23	"	"	"	—	"	—	"

1,273 waste and torn leaves weighed 35 lbs.

The average per plant was 19.3 leaves, weighing 11.5 oz. and the estimated yield per acre containing 9,680 plants was 6,332 lbs., green leaf, which would make 1,260 lbs. finished tobacco.

One plant on "Plot A." bore leaves 26 inches long by 15 inches wide and yielded 30 ounces of green leaf. Seed was saved from it.

The average weight of the stalk, after harvesting the leaves, is about 10 ounces. Sumatra tobacco averages 8 to 9 feet in height and tops at about 7 feet.

Plot B. Sumatra.

This tobacco was not cut until over-ripe, because of insufficient provision for handling the crop. Many of the lower leaves had dropped off. 1,024 plants yielded 13,228 leaves, weighing 413 lbs. 7 ounces green, the average per plant being 13 leaves, weighing 65 ounces. The average loss, through delay in harvesting, amounted to 3 lbs. 6 oz. per plant.

Plot C. Sumatra.

1,079 plants yielded 18,044 leaves, only a portion of which were weighed or measured as the crop was far past its prime.

Plot D. Section 3. Florida Cuban—492 plants.

This tobacco grows 5 to 7 feet in height and tops at 4 1-2 to 5 1-2 feet. 4,025 leaves were harvested as follows:

525	leaves,	less than	12	inches	long,	weighed	9	lbs.	11	oz.
400	"	"	12	"	"	"	9	"	13	"
563	"	"	13	"	"	"	15	"	1	"
563	"	"	14	"	"	"	20	"	9	"
526	"	"	15	"	"	"	22	"	5	"
505	"	"	16	"	"	"	24	"	12	"
369	"	"	17	"	"	"	21	"	1	"
300	"	"	18	"	"	"	19	"	3	"
200	"	"	19	"	"	"	14	"	7	"
100	"	"	20	"	"	"	8	"	5	"
50	"	"	21	"	"	"	4	"	4	"
						Total....	169	"	7	"

Each plant yielded on an average 10.6 leaves, weighing green, 6.8 ounces. Florida Cuban tobacco will stand planting 15 inches apart, in rows 3 feet apart or at the rate of 11,500 plants to the acre. The estimated yield per acre on the basis of the yield obtained is 4,870 lbs. green leaf or 970 lbs. finished tobacco.

Plot E. Section 3. *Vuelta Abajo, Cuban.*

This is a low growing tobacco averaging about 4 1-2 feet and topping at 3 to 3 1-2 feet. 210 plants yielded 1,500 leaves.

100	leaves,	less than	12	inches	long,	weighed	1	lb.	10	oz.
210	"	"	12	"	"	"	4	"	7	"
240	"	"	13	"	"	"	5	"	11	"
303	"	"	14	"	"	"	8	"	11	"
297	"	"	15	"	"	"	9	"	10	"
200	"	"	16	"	"	"	7	"	11	"
100	"	"	17	"	"	"	4	"	9	"
50	"	"	18	"	"	"	2	"	8	"
						Total....	44	"	13	"

The average per plant was 7.2 leaves, weighing green 3.4 ounces. This tobacco would stand planting 12 inches apart, in rows 3 feet apart or at the rate of 14,500 plants per acre. The estimated yield per acre is 3,080 pounds of green leaf or 616 pounds finished tobacco.

Plot E. Section 1. *Connecticut Broad Leaf.*

This tobacco grows 4 to 6 feet tall and tops on an average at 3 feet 8 inches. Some of the leaves were 37 inches long by 16 wide. 149 plants bore 2,257 leaves as follows:

294	leaves,	15	to	18	inches	long,	weighed	8	lbs.	2	oz.
407	"	18	"	21	"	"	"	34	"	14	"
523	"	21	"	24	"	"	"	32	"	8	"
367	"	24	"	27	"	"	"	33	"	1	"
280	"	27	"	30	"	"	"	3	"	0	"
21	"										
360	"	waste and over-ripe					"	18	"	1	"
							Total....	149	"	9	"

The average per plant was 15.1 leaves, weighing 1 pound. This tobacco is planted 18 inches apart, in rows 42 inches apart. It should have been spaced wider, at least 30 inches in the row and 48 inches between rows. Our yield was at the rate of 7,820 pounds of green leaf or 1,560 pounds of finished tobacco. Connecticut Broad Leaf is difficult to cure because of the extraordinary thickness of the midrib and lateral veins. None of the other varieties of tobacco grown were weighed or measured.

Connecticut Seed Leaf cured lighter than any of the other tobaccos and gave a thin, light leaf, fit for wrapper.

In the curing shed, this molded very badly. White Burley would not cure or even dry without molding. It will require a high heat to cure. It is a pipe tobacco and is also, to some extent, used as a filler in cheap, domestic cigars.

Japan Tobacco is about the same as the Broad Leaf, a wide leaf, not quite so long but with a large midrib. It is a pipe or cigarette tobacco.

Zimmer Spanish cured very dark, harsh, dry and brittle and did not absorb much moisture even in a rainy time. It is used for filler in the cheaper grades of domestic cigars.

The following tables show the leaf measurements in inches of five good Sumatra plants and the height and number of leaves of plants of some other varieties.

SOME GOOD TOBACCO PLANTS.

Sumatra.

Seed Plant	No. 1	No. 6	No. 9	No. 15	No. 17
Topped at	7′ 9″	7′ 3″	7′ 7″	7′ 9″	7′
No. of Leaves	23	27	22	25	22
Weight of Leaf	1lb. 13oz.	2lb.	1lb. 14oz.	1lb. 9oz.	1lb. 9oz.
First Leaf-Bottom	7x16	7½x14	7½x17½	7x15	7½x16½
2nd. “	8x16	6x13½	7½x18	8½x16	7½x17
3rd. “	8½x18½	8x15½	8½x19	8½x16	8½x18½
4th. “	9½x18½	8x15½	9x19	8½x17	9½x19
5th. “	9½x19	8x16½	9x21	8x16	10x19
6th. “	10x20	9x18	10x20½	9x18	10x19½
7th. “	10x20	9x17½	10½x23	9x17½	11x22
8th. “	10½x21½	9x16½	10½x22	8½x17	11x21½
9th. “	12x23	10x18	10½x22	9x18	12½x21
10th. “	13x23½	10½x18	10½x24	9x18	11½x22½
11th. “	14x24	11x18½	12¼x24½	9x19½	12x22
12th. “	13½x24	10x18	13x24½	10x20	12½x23½
13th. “	13½x24	10x18	12½x24	10x20	12½x23
14th. “	14x24½	11x19	13x25	11x19½	12½x23½
15th. “	13x24	10x18	13x26	11x20	13x23
16th. “	14x23½	9½x17	13x24	11x20½	11½x22
17th. “	14x23	9½x18	13½x25	11x21	11½x22
18th. “	12½x22	10x17	13½x24	11x19½	11½x20
19th. “	11½x22	11x17½	11½x21	11½x20½	11x19½
20th. “	12½x20	10x17	11½x20	10½x20	10½x16
21st. “	10½x15	10x17	9x15	9½x19	7½x13
22nd. “	10x14	10x17	6x12	10½x18½	4½x9
23rd. “	7x10	10x17	......	9½x16	......
24th. “	......	10½x17	......	9x15	......
25th. “	......	9½x17	......	7x11½	......
26th. “	.....	8x14	......	......	......
27th. Top	......	8x12	......	.....	......

		No. of		No. of		No. of		No. of
Variety	Height	leaves	Height	leaves	Height	leaves	Height	leaves
Conn. Seed Leaf	7′ 9″	27	8′	27	7′ 9″	28	7′ 9″	26
“ Broad “	6′	21	6′ 3″	20	7′	19	....	....
Cuban Florida	6′ 2″	18	7′	21	6′ 3″	20	5′ 9″	20
Cuban Vuelta	5′ 9″	20	5′ 8″	18	5′ 9″	19	....	....
Zimmer Spanish	5′ 3″	26	....	...	....	...	....	....
White Burley	5′ 6″	21	....	...	....	...	....	....

JARED G. SMITH,

C. R. BLACOW.

Honolulu, H. T., Apr. 10, 1905.

HONOLULU
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Hawaii Agricultural Experiment Station,

HONOLULU.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 13.

RUBBER IN HAWAII.

A comparatively new industry, the cultivation of rubber-producing plants, now engrosses the attention of planters in all tropical lands. There are probably more new areas being planted to rubber than to any other single crop, and much capital formerly invested in coffee, cinchona, tea, cotton and sugar is being diverted to this new industry in the hope that the profits will be greater than are now derived from older established enterprises.

For those interested in new rubber plantations in Hawaii the following notes in regard to the plants which are the chief sources of the world's rubber supply may be of value.[1]

In 1900 Africa produced 16,000 tons of rubber, America 31,466 tons, and Asia and Oceanica 2,339 tons, a total of approximately 50,000 tons. The world's production was estimated at 53,887 tons in 1902, 55,603 tons in 1903 and 61,759 tons in 1904. The average price for "Fine Para" in Liverpool has risen from 75 cents per lb. in 1902 to $1.14 in 1904, and has not been less than $0.75 since 1895, and has not fallen below $0.60 since 1877. This rise in price has been due to the greatly increased demand for rubber in the arts and industries without any corresponding increase in the source of supply. The outlook is that the price of rubber will continue to rise until either the price becomes prohibitive thus curtailing demand; or, an artificial substitute for this valuable product is produced synthetically in the chemical laboratory; or, until the world's cultivated rubber plantations begin to yield to the full extent of their capacity.

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[1] This is mainly a compilation from the extremely valuable monograph on the rubber plants of the world by Peter Reintgen: "Die Kautschukpflanzen, Eine Wirthschaftsgeographische Studie," Tropenpflanzer, Vol. VI, May, 1905.

No extensive new rubber forests are likely to be discovered, although investigators are almost daily adding names to the list of plants from which rubber *may be* secured. New rubbers require much experimentation before their relative commercial value becomes established.

Artificial rubbers may resemble the natural article in some one of its characteristics but none have thus far been produced which have the requisite elasticity.

As to the third solution, while there can be no doubt that cultivated rubber plantations may ultimately supplant the product of the wild trees, it will undoubtedly be a matter of decades rather than years before even a parity between supply and demand is reached. In the meantime the question arises, if we are to plant rubber, to what particular variety shall we pin our faith. A consideration of the climatic conditions under which the various natural rubber producing plants thrive will therefore first be necessary.

AMERICAN SPECIES OF RUBBER PLANTS.

Para Rubber.

In 1904 nearly fifty per cent. of the world's supply of rubber came from the Amazon valley and the major share was classed as "Para." Para rubber is, has been and probably will contnue to be the standard of excellence with which all other rubbers are compared. It is in the main derived from a large tree, *Hevea braziliensis,* Muell. Arg., which grows wild in the tropical forest on the south bank of the Amazon and its tributaries, the Rio Purus, Rio Jurua, Rio Negro, Rio Madeira, and Rio Javary-Iquitos. So far as known, *Hevea braziliensis* only rarely occurs on the north side of the Amazon, but its place is there taken by other species of *Heveas* which yield rubber of inferior quality and secondary value. *Hevea braziliensis* is a stately tree often reaching the height of 130 feet with a trunk 3 to 4 feet in diameter, the crown not very large but somewhat dense. The leaf is compound with three oval, sharp-pointed leaflets, dark-green above, bright-green on the under surface and rather prominently nerved. The flowers are small, yellowish-green, and the fruit a 3-celled capsule with 3 seeds as large as hazelnuts.

The trees are sparsely scattered through the tropical jungle over a region as large as Europe, and it is said that the native

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rubber collectors consider that a remarkably rich rubber district where the rubber trees average one to the acre. The mean annual temperature of the regions is about 83° F., with an annual range between 73° and 95°. The rainy season begins in October. By January the whole region for 2,000 miles is more or less submerged and the floods do not begin to disappear until June. During the "dry" months, July, August and September, there are frequent thunderstorms. The home of this tree is a hot, steamy, truly tropical, rich alluvial plain, almost under the equator and only slightly elevated above sea level. The tree seldom occurs at elevations greater than 600 feet. Its native habitat, so widely different from the climate of Hawaii, undoubtedly precludes the probability of its successful cultivation in these islands. There are eight or ten other rubber-yielding species of *Hevea,* some of them undescribed by botanists, all native of the upper Amazon valley. While some of these grow at higher elevations and in lands not periodically submerged their total yield is comparatively inconsiderable in quality and amount.

White Rubber. This is produced by a number of species of trees of the genus *Sapium,* native in the north-western portion of the South American continent.

Sapium Tolimense, Hort., is a native of the mountains in South Western Colombia, making its best growth at an altitude of 3700 to 6000 feet . The tree is said to grow with extraordinary rapidity, reaching a height of fifty feet with a trunk one foot in diameter in six years. It will grow at a higher elevation than coffee. The rubber is of very excellent quality. This is certainly a promising variety for introduction into Hawaii.

Sapium verum Hemsl. A forest tree 60 to 75 feet high with a trunk 3 feet in diameter, native to Ecuador and southern Colombia. It reaches its best development at an elevation of 5,500 to 7,500 feet and grows up to 10,000 feet. This tree is the principal source of the "caucho blanco" of Ecuador.

Sapium stylare Muell. Arg. A large forest tree occurring at an elevation of from 3,000 to 6,000 feet on the wet mountain slopes from Venezuela to eastern Ecuador. The mean temperature of the region where it grows ranges from 56° to 61° F.

Other species of *Sapium* growing under truly tropical conditions at lower elevations are *S. tapuri* Ule., *S. eglandulosum* Ule, *S. utile* Preuss, and *S. Marmieri* Huber. The milky sap of the latter is poisonous. These species all require higher temperatures and a greater degree of humidity than is found in Hawaii.

Black Rubber, or Central American Rubber.

The chief source of this rubber is *Castilloa elastica* Cerv. It is a native of the western slope of the Andes of Peru and Ecuador up through Central America to Mexico. The tree grows to the height of 40 to 60 feet in the open, but often reaches 120 to 150 feet in height and 6 feet in diameter in the dense and hot tropical forests. Unlike *Hevea* it will not stand wet feet but requires good drainage. It is never found in wet or swampy localities and grows best at the lower elevations in hot, sheltered inland valleys. In the equatorial belt Castilloa occurs up to 2,500 feet but at 15° either side of the equator does not grow well above 1,600 feet. It requires rich alluvial well-drained soils, high temperatures and shelter from winds. The optimum mean annual temperatures for the growth of this tree range from 77° to 82° F. It grows in Mexico where the mean yearly temperature is 72° F. and will stand a much lower one, but as the temperature and humidity decrease the growth of the tree is slower and the yield of rubber rapidly diminishes.

The leaves of *Castilloa elastica* are heart-shaped at the base, entire, bright-green and shining, those of young trees 20 inches long by 7 inches wide, those of old trees 6 to 12 inches long by 2 1-2 to 5 inches wide. The trunk of the tree is wing buttressed at the base. Rubber collectors distinguish 3 varieties depending on the color of the bark and twigs, but botanically all are considered one species.

Castilloa elastica has been widely planted. Five hundred thousand trees of this variety have been planted in the vicinity of Bluefields, Nicaragua, during the last seven years. The first of the planted *Castilloa* forests in Nicaragua has been tapped this year. Six thousand seven-year-old trees yielded 534 pounds of rubber, an average of 1 1-3 ounces per tree. A few of the largest were tapped repeatedly at 2-week intervals without injury and yielded an average equal to that secured at the first tapping. In the regions climatically suited to it *Castilloa* is considered one of the surest and most reliable species in the cultivation of which it is safe to invest the large capital required to plant and care for an artificial forest up to the time when dividends may be expected. However, it is doubtful whether its cultivation should be attempted on more than an experimental scale in Hawaii. Our mean annual temperatures and mean humidity are too low, and also the islands lie within the zone of the trade-winds, and lack the tropical climate of other island groups in equal latitudes.

Ceara Rubber is derived from a small tree usually (in Hawaii) not exceeding 25 to 30 feet in height, *Manihot Glaziowii* Muell. Arg. This tree is a native of southern Brazil. It grows on hot desert-like sandy plains and along the granitic ridges in a region devoid of running streams and with only a sparse cover of desert shrubs and low trees. The mean annual temperature of this region ranges from 82° to 90° F. The rainy season resembles that of Hawaii in that there are only occasional rains during the wet months from November to May, or June, but differs from Hawaii in that the rainy season comes in summer. Although the tree is at its best in this hot desert country it extends inland to the foot-hills, where the rainfall averages about 100 inches and where the night temperatures often fall to 60° F. or less. Like *Castilloa elastica,* the *Ceara* tree requires good drainage and never thrives in wet or swampy soils.

Ceara rubber trees will grow in a very wide range of situations. It makes an extremely rapid growth in Hawaii, thriving from sea level up to 2,500 feet on both the dry and wet sides of all the islands.

The tree is being largely planted in all tropical and subtropical countries.

The seeds are about the size of small plum pits and mottled like castor bean seeds. When planted they take a long time to germinate, unless the hard, stony outer coating is filed or abraded. Plant the seed where the tree is to grow either at irregular intervals, if in gulches or along stony ridges or other waste land, or if tillable land is to be used plow and prepare the whole field, or plant in a hole, as is often practised in the case of bananas. The distance apart should be from 6 x 10 to 12 x 15 feet, which would give from 240 to 726 trees per acre. If tillable land is used it will pay to cultivate and fertilize. On gulch, mountainous and waste lands the weeds and grass must be cut out and a space hoed around the foot of each tree as often as necessary.

A number of *Ceara* rubber trees were planted in 1893 on the land now occupied by this Station. A tree standing alone near the Tantalus road in the upper forest in the midst of a clearing, and which has been somewhat spasmodically cared for is about 40 feet high with a trunk 10 inches in diameter. Other trees planted along the trails and absolutely neglected for 12 years, overgrown by lantana and over-shadowed by Eucalyptus are now little more than 12 to 15 feet high with a trunk the size of a man's finger. So it pays to take care of trees even though common report has it that "no cultivation is required."

Pernambuco Rubber.

This formerly unimportant but of late years much-talked-of rubber is derived from *Hancornia speciosa* Muell. Arg. It is a medium-sized tree native to the dryer coastal plains and uplands from Venezuela to southern Brazil and from the Atlantic to the eastern foothills of the Andes in Ecuador, Peru and Bolivia. Unlike the *Ceara,* this tree bears rubber in every part of the plant, in the bark, wood, leaves and green fruits. The milky sap which flows from wounds becomes rubber without other treatment than exposure to the air. The flow of milk sap is greatest during the summer months. Although *Hancornia speciosa* is of very slow growth it is being substituted for coffee by many planters in southern Brazil who see only small profits in that business for many years to come.

The tree grows on a great variety of soils, and is easily propagated from cuttings. The leaves are about 2 inches long by 3-4 to 1 inch wide, acute at the base and blunt at the apex. The fragrant white flowers are about 1 inch across. The fruit is a greenish-yellow berry streaked with red, and is edible. The rubber is white and of very good quality.

These species of rubber plants are the chief sources of the American rubber supply. The genera *Hevea, Manihot and Sapium* belong to the *Euphobiaceae* or Spurge family, well known members of which are the Castor Bean, Tua-Tua and Cassava.

The milky sap which yields the rubber is contained in milk tubes in the inner or growing portion of the bark. *Hancornia* belongs to the botanical family *Apocynaceae,* while *Castilloa* is one of the *Moraceae,* a family including the fig and bread-fruit.

Of the 31,462 tons of rubber exported from South and Central American ports in 1900, 25,500 tons were derived from trees of the genus *Hevea,* 4,700 tons from *Castilloa* and *Sapium* (40% *Sapium and* 60% *Castilloa*) and 1,250 tons Ceara and Pernambuco rubbers.

AFRICAN RUBBER PLANTS.

The African rubber supply is very largely derived from species of vines of several genera belonging to the botanical order *Apocynaceae.*

Landolphia Hendelottii D. C. is a woody, slow-growing vine native to the dry hot open country from Senegambia to the western Soudan, between 9° and 12° N. latitude. While this is an important source of rubber it is considered unsuited to cultivation because of its very slow growth. It takes twenty years to attain full maturity.

Landolphia owariensis Beauv., grows in the great tropical forest region of western Africa. About half of the Kongo rubber comes from this vine. A characteristic of this species as yet unexplained is that individual plants growing side by side, and apparently identical, show wide variations in the amount of rubber which they yield,—a fact tending to discourage cultural experiments with this species.

Landolphia Klainei Pierre. Native of the Kongo forests, is considered worthy of cultivation in tropical forest regions because of its great rapidity of growth. It produces a rose-colored rubber of high value.

Landolphia Kirkii Dyer, is the most important rubber-yielding vine of east Africa, extending from the Portuguese possessions to Victoria Nyanza. It is the source of "Mozambique" rubber, which is worth about 3-4 as much as "Para."

There are many other species of *Landolphias* but these are economically the most important.

There are also a number of species of *Clitandra* and *Carpodinus* of greater or less value as rubber-producing plants.

Root rubber is derived from the roots of various herbaceous plants that grow in the open prairies or savannahs in central west Africa. The plants are pulled up by the roots, these cut off, dried in the sun and the bark peeled. The dried bark is pounded in stone mortars until the woody portion is pulverized. The rubber is gathered together, pressed into balls or cakes and is ready for export. About 1,500 tons of root rubber is the average annual crop. It is worth about 60% as much as Para. It is derived from the following species of plants:

Landolphia Thollonii, Dewevre. A woody perennial 6 to 12 inches high with strong horizontal creeping root stocks extending many yards under the surface of the ground. It grows in very dry, sandy soils in regions subject to annual prairie fires, so that while it is undoubtedly an attractive plant for cultural experiments, seeds are not easily obtained. The underground rhizomes are very rich in rubber.

Carpodinus chylorrhiza K. Schum., and *C. gracilis* Stapf, yield a very elastic brownish-red rubber. They are low shrubs 2 to 5 feet high, native of dry, desert regions of central west Africa, little known botanically, but quite important as sources of root-rubber.

Silk-Rubber.

This is derived from the milky sap of an *Apocynaceous* tree *Kickxia elastica* Preuss, native of the tropical regions of west Africa from Kameroon to the Gold Coast. It is considered one of the very best of the recently discovered rubber-producing species. In its home it grows from a few hundred to 3,000 feet above sea level and is said to require about the same climatic conditions as cacao. The milky sap of this tall forest tree is extraordinarily rich in rubber of a superior quality, as high as 58% having been found. A seven-year-old tree is reported by R. Schechter as having yielded 70.5 ounces of rubber which dried to about 60 ounces.

The sap is collected, mixed with 3 to 6 times its volume of water and is then boiled. The rubber rises to the surface, is skimmed off, washed in cold water and then pressed into sausage-shaped masses. Various salts and acids are also used for coagulating the sap without heating it. The tree is a large one, often reaching 100 feet or more in height, and in favorable situations growing with extraordinary rapidity. It does not seem to be especially particular in regard to its soil requirements, but undoubtedly requires high temperatures and a high degree of humidity.

ASIATIC RUBBER PLANTS.

The Asiatic rubbers are derived from both trees and vines.

Assam rubber. This comes from the well-known "Rubber Plant" of the horticulturist, *Ficus elastica* Roxb. This enormous forest tree is a native of the valleys and lower slopes of the whole southern Himalayas, also extending through the countries of southern Asia to Java and the Malayan archipelago. It often grows to a height of 150 to 180 feet, with a clump of trunk-like aerial roots many yards in diameter. The seeds of this tree usually germinate in the top of some nearby tree of a different species, and throw out long aerial roots which at first hang pendant but on reaching the ground themselves throw out feeding roots and increase in diameter until they reach trunk-like proportions. One of these air-roots if destroyed at the base will die below the point of injury but will throw out new aerial roots above, these in turn lengthening until they reach the ground and again throw out feeding roots. In this regard *Ficus elastica* is similar to the Ohia Lehua of the windward forests of Hawaii with its much-branched and many bodied trunks which in the beginning were really the aerial roots of the epiphytic ohia seedling.

In its native habitat this tree grows best at an elevation of from 2,000 to 3,000 feet at from 25° to 27° north latitude, and, nearer the equator, reaching to fully 5,000 feet. The temperature ranges from a winter minimum of 48° to a summer maximum of 92° F., with a yearly mean temperature of 73°. The rainfall of the forest zone where this tree grows ranges from 75 to 100 inches or more. The soils are somewhat rocky, either volcanic or sedimentary. The yield of rubber varies widely. In the total yield from individual trees this species excels all others. P. van Romburgh secured the enormous yield of 405 pounds of rubber from a very old tree in western Java (near Buitenzorg). A 23-year-old tree on an equatorial plantation in Borneo yielded 32 pounds of rubber at its first tapping. In Assam trees averaging 100 feet in height, which had not been tapped for 15 years previously, yielded an average of 10 lbs. of rubber, the next year 4 lbs. and the third year only 1.8 lbs. In New Guinea 8-year-old trees of *Ficus elastica* yielded 5.7 lbs. of rubber within a week. The growth of this tree is somewhat slow in Hawaii; nevertheless I believe that it is one of the most promising rubber trees for plantation culture, especially in such districts as Hilo, Puna, Olaa and Nahiku, where the rainfall is high. *Ficus elastica* will stand low temperatures that are extremely detrimental to the Para and Central American rubber trees.

Practically all the rest of the Asiatic rubbers are derived from vines. It is doubtful whether any of these could be successfully and profitably transplanted to Hawaii.

THE BEST RUBBER TREES FOR HAWAII.

Hawaii with its subtropical rather than truly tropical climate, is limited to a very few species of rubber-producing plants. The most suitable species of those above enumerated are undoubtedly in the order of their importance *Manihot Glaziowii* and *Ficus elastica*. The first of these, the *Ceara* rubber tree, should comprise the larger proportion of all new plantations, because of its extremely rapid growth and early maturity. In laying out a rubber plantation comparatively early returns are desirable. The *Ceara* trees will stand a moderate tapping when three years old, and may be counted on to yield a considerable return in five years.

The Assam rubber tree, *Ficus elastica,* while of much slower growth, yields much more abundantly when it does finally reach a bearing age. This is also true of the Manicoba rubber, *Hancornia speciosa.* The white rubbers, *Sapium Tolimense, S. verum* and *S. stylare,* native of high elevations where the climatic conditions are similar to those of our own mountain slopes, would seem to be promising for experiment, provided seeds can be obtained.

WILD AND CULTIVATED RUBBERS.

Practically all the rubber thus far marketed has been derived from wild trees. The collection of rubber by the native races of all countries has been extremely destructive, in many instances resulting in the extermination of the rubber-producing species over wide areas. This factor alone has had much to do with the rapid rise in value of this article. The discovery of a new rubber-bearing species or of a new forest in some hitherto unexplored region means the rapid destruction of this source of supply, because governmental control of the native rubber gatherers is absolutely impossible, and attempts at restraint or supervision worse than futile. The native collector wants to get as much as he can today, so that he will not have to work tomorrow. Enormous forest trees, perhaps hundreds of years old, are felled or hacked and mutilated so that they soon die and rot, and for his trouble the native secures on an average hardly one per cent. of the total amount of rubber in the bark, but that which he gets costs him only the labor of gathering it. There is no investment of capital. No taxes have been paid on the lands producing the raw material, and there has been no expenditure for labor or permanent improvements and executive management of the enterprise.

In the case of a plantation for the production of rubber on a commercial scale, the points to be considered are not merely the adaptability of certain rubber-bearing species of plants to certain soils and climatic conditions, but it is fully as important to so conduct the enterprise during the first unproductive years that the total capital invested when production finally begins shall not be so large as to preclude the possibility of average dividends. The robbery of cultivated trees after the manner of the native rubber collectors is of course entirely out of the question. A plantation management must evolve methods of gathering rubber in such a manner that the trees will not be destroyed and yet so that they will produce to the very maximum of their capacity. Fungus diseases and insect pests will undoubtedly appear. The question of how much or how little cultivation is necessary will have to be worked out in a practical way. In other words, the cultivation of rubber is an experiment and until it has passed the experimental stage no one knows to what extent it will be profitable.

The outlook is good viewed from the standpoint of an increasing demand for the product.

Conditions in Hawaii are apparently extremely favorable for the cultivation of the *Ceara* trees. One of the newly formed companies have already planted 100,000 seeds of this species, and expect to have half a million trees growing within another two years. If our planters succeed with rubber as they have with sugar, and put into the business as much science, skill and knowledge as they would into any other new enterprise there can be absolutely no question of ultimate success. The planters of Hawaii stand on an equal footing with those of any other of the tropical countries of the world in that the cultivation of rubber is as yet everywhere only an experiment.

JARED G. SMITH,
Special Agent in Charge of Hawaii Experiment Station.

HONOLULU, H. T., *July* 20, 1905.

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Hawaii Agricultural Experiment Station,

HONOLULU.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 15.

LIME AN ESSENTIAL FACTOR IN FORAGE.

By EDMUND C. SHOREY,

Chemist, Hawaii Experiment Station, United States Department of Agriculture.

The scientific feeding of live stock is to so feed, that the purpose for which the animal is reared or kept is accomplished without waste of nutrient material. When a ration is so compounded that this result is obtained, the ration is said to be balanced. In balancing rations consideration has for the most part been given to the ratio between the protein on the one hand and the carbohydrates and fat on the other. These are food ingredients proper. They furnish heat and energy, as well as replace the waste of the body. In addition to these, certain inorganic, or ash, ingredients are necessary for animal life or growth. Among these the most important are, phosphorus, sulphur, lime, iron and potash.

In the course of analysis of a number of Hawaiian grown fodders[1] it was found that many contained so little lime that it would be impossible for an animal to eat enough to obtain what is usually recognized as the requisite amount of this ash ingredient.

This lack of lime in many of our grasses and forage plants no doubt explains the failure to obtain the best results, which sometimes follows the feeding of what is otherwise a properly balanced ration.

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[1] These analyses will be published in full as Bulletin No. 13 of the regular series of this Station.

The Function of Lime in the Plant:—The role which lime plays in plant life is not very well understood. It is usually absent from young tissues, and is found for the most part in the walls of adult cells, where it is present in organic combination. It may also be present as a by-product as crystals of oxalate of lime deposited in the cells. The higher plants cannot develop normally without lime, and for this reason it is regarded as being necessary for plant life.

Function of Lime in the Animal:—Lime forms an essential part in the bones of animals and it is abundant in milk. More than 2% of the live weight of a full grown, well fed steer is lime. Cows' milk contains more lime than does lime water,[1] generally in excess of 0.15%. Lime constitutes about 20% of the ash of milk, and generally more than 1.5% of the total solids.

A lack of lime in food will result in improper bone development in the growing animal. This impaired development of the bony skeleton will of course react on the general growth of the animal, and the purpose for which the animal is fed, whether it be the production of beef or milk or of work, will not be attained. In extreme cases a diseased condition of the body may result.

Sources of Lime:—Lime enters the animal body both in food and drink. All flowering plants contain some lime, as do all natural waters. Surface waters, however, in Hawaii, except in coral formations, contain but small amounts of lime or other mineral ingredients. Whether lime in the form of purely mineral salts such as carbonate or sulphate present in water, is as good a source of lime for the animal as the organic combination present in plants, is not known. In fact the whole question of the needs of animals for mineral food stuffs has been neglected, and published analyses for the most part, give the total ash without any consideration of its composition.

Lime Varies in Foods:—The variation in the lime content

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[1] Lime water is a saturated solution of lime in water. At 80° F. such a solution will contain about 0.09% lime.

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of materials used for human food is shown by the following figures:

100 lbs. dry material	Contain lbs. lime.
Beef	0.029
Wheat	0.065
Potato	0.100
Egg albumen	0.130
Peas	0.137
Human milk	0.243
Yolk of egg	0.380
Cows' milk	1.510

In fodder plants and materials the variation is quite as wide. There are three factors which influence this variation which should be considered in this connection:

I. Different species of plants growing under the same conditions have the power of taking up from the soil, and incorporating in the plant tissues different amounts of inorganic substances. As an example of this, sorghum and alfalfa growing side by side were found on analysis to contain:

	Sorghum	Alfalfa
Potash	0.41	0.84
Lime	0.05	0.45
Phosphoric Acid	0.15	0.30

II. Plants of the same species grown upon different soils may contain different amounts of ash ingredients. If an ash ingredient is present in the soil in a soluble form, in large excess over the needs of the plant, the plant tissues will contain an excess of this ingredient. A marked example of this was noted in comparing sisal fiber from Sisal Plantation with that from the Experiment Station. The total ash in each was approximately the same. In the case of the fiber from Sisal Plantation where the soil is disintegrated coral, 40% of the ash was lime, while in that from the Experiment Station, where the soil contains less than 1% lime the amount was but 7%.

III. Different parts of the same plant contain different amounts of ash ingredients. In other words the mineral matter taken from the soil becomes localized in the plant. Seeds are rich in phosphorus, leaves and straw in potash, old mature cells richer in lime than growing parts.

Amount of Lime necessary:—It has been found that to maintain full grown oxen the fodder should contain 0.10 lb. of lime per day. In the case of milch cows a yield of 20 lbs. of milk would contain 0.03 lb. lime, and from this it may be concluded that approximately the amount of lime required by milch cows is 0.13 lb. per day.

The food capacity of an average cow or steer may be taken as approximately, 100 lbs. of green fodder per day. Among the fodder samples analyzed, a large number were found to contain so small an amount of lime that in order to obtain 0.13 lb., the animals would have to eat green fodder much in excess of 100 lbs. per day.

Fodders Low in Lime:—The following examples will sufficiently illustrate this:

Sample	% Lime	Lbs. green fodder necessary to furnish 0.13 lb. Lime.
Sorghum (4)	0.05	260
Cane Tops	0.01	1300
" " (2)	0.04	325
Para Grass	0.06	216
" "	0.08	162
" "	0.09	144
Kaffir Corn	0.01	1300
" "	0.04	325
Millet	0.04	325
Cassava Root	0.07	185
" "	0.04	325
Panicum crus-galli	0.02	650
Hilo Grass	0.08	162
Buffalo Grass	0.06	216
Pilipiliuli	0.02	650
Kukaipua	0.06	216
Eleusine indica	0.04	325

A number of samples of grasses both wild and cultivated, were found to contain lime in excess of these figures. One sample of sorghum contained 0.15%. Guinea grass (2 samples) 0.22 and 0.17%. Manienie or Bermuda grass, 0.14%. Paspalum dilitatum (2 samples) 0.10 and 0.12%. Pili grass 0.26%. While too few samples have been analyzed to warrant making any general statement as to average composition, there are sufficient data to warrant the conclusion that forage plants of the grass family grown in Hawaii, are low in lime; some extremely so.

Among the concentrated fodders used to increase the amount of protein in the ration, many are low in lime. A sample of bran was found to contain but 0.07% of lime, requiring 200 lbs. per day to give the required amount. Rice bran, (two samples) contained 0.15 and 0.08% respectively. Cocoanut meal, 0.08%. Barley contains 0.05 to 0.10%. It is easily seen from these figures that these concentrates in the amounts used to balance a ration, cannot make up any deficiency of lime in a sorghum or grass ration.

Fodder Material High in Lime:—Among green fodders the legumes are decidedly higher in lime content than the grasses. Two samples of alfalfa were found to contain 0.45 and 0.41% respectively. Spanish clover (*Meibomia uncinata*) 0.19% and *Meibomia triflorum* 0.70%. Algaroba beans (two samples) contained 0.28 and 0.34% respectively. Two samples of algaroba seeds alone, contained 1.00 and 1.10%.

Among miscellaneous fodder materials furnishing lime, may be mentioned dried brewers grains with 0.25%, linseed meal 0.40% and waste molasses. The lime content of waste molasses is quite variable and it is not possible to state the average amount present. Two samples of molascuite or sugar bran made from such molasses, contained 0.87 and 1.00%.

Consequences of Feeding a Ration Deficient in Lime:—The results which follow a lack of lime in the fodder have been already outlined but it is desired to emphasize particularly one point; the relation of lime to milk production. Experimental data are lacking on this point, but physiological considerations point to the conclusion, that the amount of lime in the fodder may very easily be the limiting factor in milk production.

The amount and composition of the ash in the fluids, blood, milk, etc., of an animal body are remarkably constant. There is, in health, a constant adjustment of the distribution of the mineral ingredients, and any wide variation from the normal ash composition of the fluids of the body is an indication of diseased or abnormal conditions. Those who have to do with live stock generally realize the importance of lime to the young growing animal in furnishing bone material, but many do not realize the comparatively large amount of lime in milk. This high lime content is of course really a provision of nature to meet the needs of the young animal.

There is abundant evidence to prove that the lime content of cows milk does not vary, except within narrow limits, even under very diverse conditions of feed. In the case then, of a milch cow fed a ration deficient in lime, the milk secreted still contains approximately the same percentage of lime, and to meet the deficiency of lime in the food, either the production of milk must decrease or the deficiency be made up from the tissues of the body. In the latter case the general health and vigor of the cow is affected, resulting ultimately in a decrease in the milk.

How to Meet a Deficiency of Lime in Fodder:—In a general way the answer to this question is suggested by the foregoing statements of analyses. Shortly it may be said that a deficiency of lime in fodder may be met:

1. By growing a larger proportion of leguminous crops for green fodder.
2. By feeding such concentrates as algaroba beans, waste molasses or products made from it.
3. By supplying natural water containing more lime, or lime water.
4. By the application of lime or fertilizers containing lime to forage crops of the grass family. Armsby in his Manual of Cattle Feeding, recommends the use of leached wood ashes sprinkled over the food.

For range cattle the introduction of legumes on the ranges or such grasses as may be found to take more lime from the soil, are the most obvious remedies.

Cases are on record in Hawaii, where cattle have become diseased from the lack of lime in grass fodder. When such conditions indicated by emaciation, soft bones, etc. arise, a veterinarian should be consulted.

HONOLULU, T. H., January 2, 1906.

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Hawaii Agricultural Experiment Station,

HONOLULU

J. G. SMITH, SPECIAL AGENT IN CHARGE

PRESS BULLETIN No. 16 *

THE AVOCADO MEALY-BUG

(*Pseudococcus nipae* Mask.)

BY D. L. VAN DINE,

Entomologist, Hawaii Experiment Station, United States Department of Agriculture

The enemy of the Avocado or Alligator pear (*Persea gratissima*), commonly known in and about Honolulu as the "blight of the Alligator pear" or simply as "pear blight," is, properly speaking, not a blight at all but an insect, one of the mealy-bugs, *Pseudococcus nipae* Mask., belonging to the same family, *Coccidae*, as do scale-insects. This family is related to the plant-lice and leaf-hoppers of the order Hemiptera. "Blight" is a term in common use by botanists, or rather plant pathologists, to designate certain fungus diseases of plants, these fungi being low parasitic forms of plant life. Besides the great injury and disfigurement caused by this mealy-bug to the foliage, fruit and leaf buds, and terminal branches of the Avocado, the pest infests the fig, grape, guava and breadfruit.

The Avocado mealy-bug was described in 1892 by Mr. W. M. Maskell under the name *Dactylopius nipae*. The specimens were received by Maskell from Demerara and were taken from an aquatic palm, *Nipa fruticans*.[1] The insect is recorded for the first time in the United States in the Canadian Entomologist with the following note: "Found for the first time in the

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* Reprint of Press Bulletin No. 8

[1] Trans. and Pro., New Zealand Institute, 1892, Vol. XXV (1893) pp. 232–233.

U. S., in the Harvard botanical greenhouse at Cambridge, Mass. Introduced."[2] Mrs. Fernald in her catalogue of the Coccidae of the world records the species from Demerara, Mexico and Massachusetts.[3]

GENERAL ACCOUNT.

The Avocado mealy-bug and its related forms, including the scale-insects, represent the most injurious family of insects with which the horticulturist in a tropical country has to contend. The short life-cycle and immense increase in succeeding generations render them capable of appearing in enormous numbers on their respective food plants within a very limited space of time and, in many instances, before their presence is detected by the owners of the trees or plants. The ability to recognize these insidious foes before serious injury is accomplished will enable the grower to check the increase before the pests become epidemic.

In general the life-history of the members of the family Coccidae is as follows: The young, with few exceptions, are hatched from minute eggs. It is during the egg state, particularly, that these serious plant pests have been transported long distances, making the distribution of many species almost world-wide. The young possess legs, a distinct head and their mouth-parts are formed for sucking. Soon after hatching, they disperse over the plant to feed. This they do by inserting their beak-like mouth or proboscis into the tissues and sucking from the plant its sap. The result of myriads of individuals engaged in this operation can be imagined to have a very disastrous effect on the health and even the very life of the infested plant. As growth and the consequent development take place, these small insects cast off their skins to provide for the increase in size. During the developmental period the males are not unlike the females in appearance.

When full-grown the females remain stationary or practically so, having undergone an incomplete metamorphosis. All the female Coccidae are either partly or entirely covered by a wax-like, scaly, powdery, or cottony excretion and also in some in-

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[2] King. Can. Ent., Vol. XXXIV, No. 3, 1902, p. 59.

[3] Bul. 88, Mass. (Hatch) Experiment Station, 1903 p. 107.

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stances further enveloped in the adult stages by the addition to such excretion of the cast skins of the younger stages. The waxy covering of the female insect affords a place of protection to the eggs and newly hatched young and offers more or less resistance to the action of the various insecticides in use to destroy them. In some instances the covering is scale-like, in others cotton- or meal-like. Thus we have the common names, as for example, scale-insect, mealy-bug and cottony cushion-scale. The conspicuous part of the Avocado mealy-bug is its white meal-like covering. The color of the body is yellow varying to orange. On slight pressure the body of the fully matured female exudes a bright orange fluid. Fully developed females are represented on the under side of a leaf in figure 1.

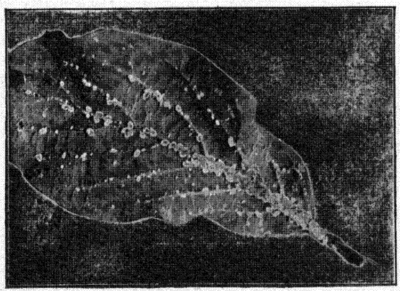

Fig. 1.—The Avocado mealy-bug, *Pseudococcus nipae* Mask., on the underside of a leaf of the Avocado. (original).

The males when fully developed form about themselves a cocoon and after undergoing a complete metamorphosis issue therefrom in the adult form with a single pair of wings. They are minute in size and would not be observed by the plant grower. In fact the males of many species are little known scientifically.

Both sexes are active while young and travel from tree to tree where the limbs of an infested tree overlap the limbs of another. They are also blown about on leaves by the wind or carried by water. They are distributed in some instances by species of ants associated with them; and, in the course of commerce, are carried from one locality or country to another on their food plants or the products of the same.

OCCURRENCE IN HAWAII

The Avocado mealy-bug is first recorded in Hawaii by Mr. R. C. L. Perkins in 1902. He says:

> At the present time probably the two most injurious scale insects are the purple scale, *Mytilaspis citricola*, of the citrus trees and the white *Eriococcus?* of the alligator pear, guava, and other trees. Though the male scale of the latter is readily eaten by several ladybirds, a good enemy for the female is much needed.[4]

The writer in the annual report of this Station for the fiscal year ending June 30, 1902, says:

> The trees of the Hawaiian Islands suffer continually because of the presence of an unusual number of scale-insects, plant-lice, and mealy-bugs. One species of the latter pest (*Dactylopius* sp.) is at present doing great injury to the Alligator pear, or Avocado, in the vicinity of Honolulu. Many trees have died and all are injured to a greater or less extent. The application of kerosene emulsion has been used with success in several instances and will be advised as a remedy, together with proper pruning and cultivation.[5]

Mr. Wray Taylor in his report as Commissioner of Agriculture and Forestry for 1902, writes:

> The most troublesome blight that has made its appearance is the *Eriococcus* on the alligator pear, fig and guava trees. About four thousand small black ladybirds, name unknown to our entomologist, caught in Hilo, were scattered in and around Honolulu, but they have not done the work it was thought they would. Resin washes have been effective in many instances, and would be more so if those complaining of the blight would spend a little more time in using the washes.[6]

Specimens of the Avocado mealy-bug taken in Honolulu from the Avocado and guava were forwarded on Sept. 9, 1903, to Dr. L. O. Howard, Bureau of Entomology, U. S. Department of Agriculture. Dr. Howard replied under date of Oct. 3, 1903, that the material represented *Dactylopius nipae* Mask. Mrs. Fernald refers the species to the genus *Pseudococcus* in her catalogue. Mr. G. W. Kirkaldy in his "Preliminary List of the Insects of Economic Importance Recorded from the Hawaiian Islands"[7] and also in "A List of the Coccidae of the Hawaiian Islands"[8] records the species under the name *Trechocorys nipae* Mask., in his opinion both *Dactylopius* and *Pseudococcus* being synonyms. The first economic account of this species is by the writer in 1903.[9] Among others, a copy of this article was sent to Prof. T. D. A. Cockerell. Prof. Cockerell in acknowledgement said:

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[4] Rep. of the Governor, Ter. of Hawaii, Year ending June 30, 1902, Washington, 1902, pp. 35, 36.

[5] Ann. Rep., Hawaii Experiment Station, 1902, Office of Experiment Stations, U. S. Dep't of Agriculture, Washington, 1903, p. 325.

[6] Rep. of the Comm. of Agri. and For., Ter. of Hawaii, for the period ending Dec. 31, 1902, Honolulu, 1903, pp. 36, 37.

> With regard to *Dactylopius nipae*, there are two apparently distinct species which are usually confused and you might perhaps look at your form with this in view. The other species, *D. pseudonipae*, is best distinguished by the *male* being yellow. The antennae of *pseudonipae* (female) are always 7-jointed, those of *nipae*, 7 or 8-jointed. *D. pseudonipae* is usually found on palms.

On Feb. 12, 1905, the writer took specimens of a mealy-bug very similar to the Avocado mealy-bug from a palm *Acanthophoenix rubra* in Honolulu and forwarded the same to the Bureau of Entomology of this Department. These were determined by Mr. J. G. Sanders as *Pseudococcus pseudonipae* Ckll.

NATURAL ENEMIES.

Several ladybird beetles have been observed feeding on the Avocado mealy-bug of which one, *Cryptolaemus montrouzieri* Muls., is especially abundant. This species is a mealy-bug feeder and was collected by Koebele in Queensland in the Spring of 1894 and forwarded to Honolulu where it was received and liberated by Mr. Joseph Marsden, then Commissioner of Agriculture and Forestry. In his report for 1894, Mr. Marsden has the following regarding the work of this predaceous beetle.

> The work of one ladybird (*Cryptolaemus montrouzieri*), has been truly marvellous. A year ago, and for the past three years, all the citrus trees

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[7] Hawaiian Forester and Agriculturist, Vol. I, No. 6, 1904, p. 154.

[8] The Entomologist. (September), 1904, p. 227.

[9] The Mealy Bug or "Pear Blight" of the Alligator Pear. Press Bul. 8, Hawaii Experiment Station, Honolulu, 1903, pp. 6, figs. 3.

> (such as the tamarind, orange, lime and lemon) were affected by a blight that was terribly destructive, so much so that it seemed that if relief was not soon obtained the citrus trees would all be destroyed. Many of the trees in fact did succumb to the effects of the blight which Mr. Maskell has named the *Dactylopius albizzia.* The Cryptolaemus soon got to work on this blight, and increased to such a wonderful extent that the ground, walls and fences were soon covered with full-grown, crawling, white larvae seeking suitable places to pupate and transform into the imago, or perfect stage. Tens of thousands of the larvae were collected and shipped to all parts of the Islands wherever any of the Dactylopids were known to exist. A great number were shipped to Kona to attack the coffee blight (*Pulvinaria psidii* Mask.), which also belongs to the Dactylopidae. For a time the most encouraging reports came of the work this ladybird was doing on the coffee blight, but latterly letters have been received stating that the bugs do not increase; this is but natural. The ladybirds have certain times for breeding, usually during the summer months, and during the winter they hibernate. This seems to be the case with the Cryptolaemus, for now hardly one can be found in Honolulu, where three months since hundreds of thousands were to be seen. The work of this bug has been so effective that many orange and tamarind trees that for the last three years have borne no fruit and looked as if they would eventually succumb, have this year come out in full foliage and fruit. Another serious blight (*Dactylopius longifilus*) made its appearance on the Samang and many other trees, and threatened to prove a troublesome pest. The Cryptolaemus, however, made short work of it, and hardly a vestige of it can now be found.[10]

This ladybird beetle is one of the most active of Koebele's introduced beneficial insects. Prof. Koebele says in his report for 1897, speaking of scale-insects:

> Up to the present time, some sixty species of these have been found on the Islands, and some of them would have made it utterly impossible to raise the citrus and coffee trees successfully, in fact, most of the shrubs and trees at the time were so infested by the then recently introduced and most pernicious coccid ever met with, *Dactylopius vastator* Mask., (*Pseudococcus filamentosus* ckll.) that their destruction in the near future seemed imminent had not relief been brought. Without doubt their destructive work would spread over all the Islands, notwithstanding the most diligent prevention on your part. The scale had not been met with as yet in any of the other Islands, and at present wherever it may appear, its enemies are awaiting it, the chief of which is the Australian ladybird, *Cryptolaemus montrouzieri* Mulsant.[11]

In speaking further of another mealy-bug, *Dactylopius ceri-*

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[10] Rep. of Comm. of Agri. and For., Rep. of the Minister of the Int., Republic of Hawaii, nine months ending Dec. 31, 1894, Honolulu, 1895, pp. 33, 34.

[11] Rep. of the Ent. to the Hawaiian Gov't. for the two years ending Dec. 31, 1897, Haw. Pl. Mo., Vol. XVII, No. 5, 1898, p. 208.

ferus Newstead, (*Pseudococcus virgatus* Ckll.) Koebele says that "This species also is kept in check by the Cryptolaemus beetles, which increase to such an extent in the early summer that millions of their larvae can frequently be seen crawling around where the coccids (mealy-bugs) abound."

Mr. F. W. Terry thus describes this beneficial beetle:

> Adult. Distinctly oval, the elytra (wing covers) black, except at the posterior extremities, which are similar in coloring to that of the thorax, i. e., orange brown. The fine whitish hairs which cover the body produce a somewhat greyish effect.
>
> Larva. The larva is really a dark brownish grey, but the body is completely hidden by a dense fluffy covering of white wax. Four longitudinal rows of white pointed filaments project irregularly beyond the general mass. The general appearance of this larva is so like that of a large mealy-bug, that they are often destroyed as such. Their active movements, however, soon enable the careful observer to distinguish them from their stationary prey.[12]

It is regrettable that this mealy-bug enemy is not as efficient a check to the pest under discussion as it has proved to be of certain other species and it follows that the fruit grower must employ active measures of suppression if he would grow the plants infested by the Avocado mealy-bug. A rather detailed account of the above ladybird beetle is given in order that the practical man may appreciate its value to him in its work against other enemies of his plants and recognize it as a species worthy of his attention and protection. On the other hand, when a plant becomes infested with an insect pest and it is obvious that if unchecked its presence becomes a menace to the development of the plant, the idea is absurd that spraying or fumigatation should not be employed because of the resulting iujury to the beneficial species associated with the pest. In no other country are the natural enemies of insect pests better understood or appreciated than in the United States yet the economic entomologists of the various agricultural institutions agree that to cease the active warfare against the enemies of the field and orchard would be nothing less than suicidal to the agricultural interests of the country.

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[12] The Hawaiian Forester and Agriculturist, Vol. 1, No. 11, 1904, p. 300, 301.

REMEDIES

Cultural methods:—Up to the present time there has been no effort to cultivate the Avocado or Alligator pear in these Islands. There are no orchards, as we understand such plantings on the Mainland. The conditions under which the trees are growing in closely planted door-yards, does not favor vigor and productiveness. The lack of cultivation and fertilization affects the vitality of a tree or plant and an unhealthy plant is readily attacked by its insect enemies and their increase promoted. Vigorous cultivation and supplying by fertilizers the needful plant food are recognized as direct aids to trees and plants in enabling them to withstand insect injury.

Kerosene emulsion:—The insecticide that will prove the most effective against the Avocado mealy-bug and other related pests is an emulsion of kerosene or coal-oil. The mixture is prepared as follows:

Dissolve one-half (½) pound of whale-oil soap (or any hard laundry soap shaved fine) in one (1) gallon of water while the water is boiling over a fire. When the soap is thoroughly dissolved, remove the solution a safe distance from the fire and pour it into two (2) gallons of kerosene (coal-oil). Empty coal-oil tins from which the tops have been removed will do as containers. While hot the mixture should be churned or agitated voilently until the oil is thoroughly emulsified with the soap and water solution. A perfect emulsion is best secured by using a strong force pump to pump the mixture back into itself, the nozzle having an opening throwing a direct stream. By this means a perfect emulsion can be made in from five to ten minutes. If the emulsion is perfect, it will on cooling have a thick, creamy consistency and *no free oil will rise to the surface.*

A good type of pump for use in preparing kerosene emulsion is illustrated in Figure 2 at B. The above mixture is a *stock* solution and must always be diluted before applying to the infested tree or plant. If on dilution free oil is in evidence, the mixture should not be used but the stock solution should be re-heated, being careful not to allow the oil to take fire, more soap should be added and the mixture again agitated. Very hard water will not make a good emulsion and if the water is hard, it may be found necessary to use rain water or soften the water by the addition of lye. The emulsion will keep perfectly well for several weeks and should not be diluted until wanted for use.

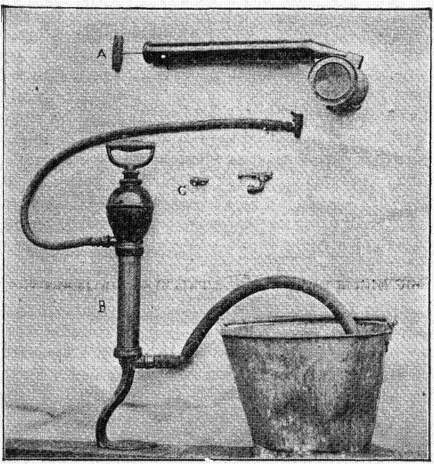

FIG. 2—A strong force pump (B), especially useful in preparing kerosene emulsion. The nozzle can be adjusted to throw either a direct stream or a spray. (original.)

Kerosene emulsion vs. *resin wash:*—The ingredients entering into the composition of kerosene emulsion are common commodities of the household while the substances used in the preparation of resin wash are not, and, in some instances, are not easily attainable. On the market in Honolulu they are, moreover, more expensive than in localities on the mainland. Kerosene emulsion can be made in a few minutes while the resin wash takes at least two hours of constant boiling and attention. Resin wash is preferably used while warm and in some instances must be re-heated before dilution because of a characteristic sediment on standing. Kerosene emulsion is easily diluted when cold and heating does not increase its effectiveness. Resin wash acts principally as a covering to the pests, killing by suffocation. This property necessitates its remaining on the infested plant for a considerable period and therefore, because of the variable and frequent rains, the quicker acting and caustic kerosene emulsion is better suited to Hawaiian conditions. Kerosene emulsion kills by contact and is practically immediate in its action. The resin wash has been used with great success in the control of certain scale-insects as a winter wash in temperate-zone localities where the absence of foliage permitted the use of a strong solution or in other localities during seasons when the absence of rain would insure the wash remaining on the plants for a period of several weeks.

Spraying:—In using the kerosene emulsion as a remedy for the Avocado mealy-bug, dilute one part of the stock solution with fifteen parts of water. Agitate the mixture thoroughly and apply with a spray pump. This strength is not sufficient to kill all the forms of the mealy-bug but is necessitated by the danger of injury to the foliage. Concentrated washes and strong solutions cannot be used in the warfare against plant pests in Hawaii because of the variability of plant growth and the fact that the plants are in constant leaf. The plants and trees are, in comparison to temperate-zone plants, quick growing and succulent with a resulting lessening of the power of resistance to the action of spraying mixtures. Many of the common trees and shrubs would be killed out by a single severe frost. As regards the Avocado, the above strength will kill the immature forms with the exception of the eggs and the very young still protected beneath the adult females.

The spraying should be repeated in about two weeks to kill the forms that have developed and dispersed over the tree in the meantime. In the case of badly infested trees it has been found necessary to spray still a third time, between three weeks and a month after the second application, to kill the immature forms that have arisen from the adults that escaped the previous operations.

If the trees are sprayed before the new growth starts preceding the bearing season, a much stronger solution may be used. A solution consisting of one part of the stock mixture diluted with only nine parts of water can then be applied. The old leaves are then dropping and there is no new growth to be injured. This strong solution should not be used before the old leaves begin to drop or after the new fruit and leaf buds start. One thorough spraying at this time with the above strength will kill nearly all of the mealy-bugs and if a second spraying with the weaker dilution is given after the new growth has started, the trees will be well cleaned of the pest. Thereafter the new growth should be carefully inspected for the appearance of the young forms and if observed, the spraying with the weak dilution should be repeated.

The base of the tree should be wrapped with gunny sacks during the operation of spraying to prevent the emulsion running down the trunks and, collecting at the crown, causing injury. The spraying should not be done in the noon-day heat of the sun for there is not only a greater possibility of injuring the foliage but also there is a rapid evaporation of the oil and a consequent lessening of the length of time for the emulsion to act on the pests. Spraying on windy days should also be avoided since the spraying is uneven, a great deal is wasted and evaporation is rapid.

The emulsion should be applied to the *insects* and not to the *tree*. All infested portions should be treated since a single infested branch if overlooked, becomes a menace to the rest of the tree. The emulsion must be applied as a finely divided spray or mist which when brought in close proximity to the infested portions of the tree will settle evenly over the mealy-bugs. Treat the inner part of the tree first and then commence at the top on the outside and spray one side of the tree at a time. Collect and destroy all leaves that fall and destroy all guavas growing wild in the vicinity of the trees since they harbor this pest.

Spraying apparatus: Through the efforts of this Station, several types of spray pumps and accessories suited to the present demands in Hawaii are on the market in Honolulu. The pump best adapted to prepare the emulsion has already been referred to and is shown in Figure 2. With the exception of areas devoted to pineapples and coffee and several plantings of fruit trees of greater or less extent (including Citrus, Avocado, Fig, Mango and Papaia trees) there is no demand for an elaborate spraying outfit. The general demand is for what might be termed a "dooryard outfit." After many trials, the most satisfactory and cheapest machine has proved to be a 5-gallon bucket outfit to which has been attached an extra length of hose and an extension rod. Such an outfit is illustrated in Figure 3. For the reason that a spray will not carry any distance the nozzle must be brought in close proximity to the part of the tree to be treated. This is done by means of the extension rod. Several barrel outfits mounted on wheels have been purchased for use by owners of larger plantings of fruit trees. The use of these results in a large saving of labor and time. The type is one selected by this Station and recommended after a thorough trial. Since the bucket outfit meets the present demand, it is deemed unnecessary to discuss the question of pumps more in detail. The Station invites inquiries on any phase of the subject and is prepared to give definite advice on the type of pump needed in any particular case, its cost, where it can be obtained and will give also personal instruction in the operation of spraying.

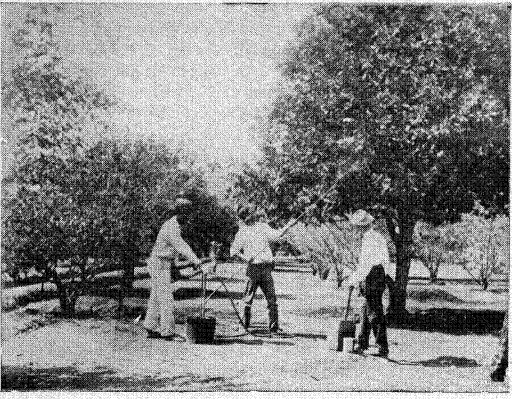

FIG. 3—Bucket-outfit supplied with an extra length of hose and an extension rod in use against a scale-insect on an orange tree. (original.)

Honolulu, T. H., *January 13, 1906*.

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Hawaii Agricultural Experiment Station,

HONOLULU

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 17.

THE MANGO WEEVIL.

(*Cryptorhynchus mangiferae* Fabr.)

BY D. L. VAN DINE,
Entomologist, Hawaii Experiment Station, United States Department of Agriculture.

The destructive work of the mango weevil in the seeds of mangoes was noted in Hawaii for the first time last year. The nature of the insect and its injury point it out to all persons interested in the culture of the mango as a serious pest. In the family Curculionidae, to which this beetle belongs, occur numerous species of the most injurious character. The cotton boll-weevil has destroyed over $50,000,000 worth of cotton in the Southern United States since its appearance in Texas in 1892. The curculios of the apple, plum, quince and strawberry do enormous damage to these and related fruits. The chestnut weevil and the acorn weevil, extending their injury to other nuts, have added greatly to the evil reputation of this family of beetles. Looking in the future to the Mainland as a market, it is readily seen that to prevent an embargo on mangoes, this enemy must be controlled and its widespread distribution throughout the islands of the group prevented. The present limited knowledge of the mango weevil is herewith presented to aid those interested in the problem in formulating an outline of warfare.

ITS HISTORY

Mr. E. A. Schwarz, of the United States Bureau of Entomology, to whom the writer is indebted for the determination of the mango weevil, says in a letter, under date of July 26, 1905:

> The weevil is *Cryptorhynchus mangiferae,* originally described by Fabricius (Systema Entomol., p. 139, 1774) without locality. Since that time it has often been described and figured. I think that, after all, the best description is that by Boheman in Schoenherr's Gen. et. Spec. Curc., vol. IV, pt. I, p. 91. Its original home is uncertain, for since many years it has spread (no doubt through the agency of man) throughout the "Oriental Region" from Madagascar through India, Ceylon, etc., to Java and other Malayan Islands. It probably occurs now also in many of the islands of the Pacific Ocean, although I fail to find any records. The species is not enumerated by Sharp from the Hawaiian Islands and is no doubt a recent introduction there.
>
> The weevil appears to be extremely injurious to mangoes, and accounts of its ravages are numerous. The literature is, however, not easily accessible, the most available reports being in the "Indian Museum Notes" (at several places). A paper on the mango weevil by Mr. Simmons, read before the Calcutta Microscopical Society is referred to in *Nature,* Vol. 37, 1888, March 22, p. 492, and there seems to be a full account in a work (which I have not seen) entitled "Les insectes nuisibles au Manguier a l'ele Maurice" par D. L'Emmery de Charnoy, Paris, 1898. The oldest economic and illustrated account appears to be by Hubner in the "Naturforscher," vol. XXIV, 1789, a publication quite unknown to me. Larva and pupa are tolerably well figured in the "Indian Museum Notes."

The following is taken from an article by Mr. E. C. Cotes in the "Indian Museum Notes":[1]

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[1] E. C. Cotes, Further Notes on Insect Pests, Indian Museum Notes, Calcutta, vol. I, 1889-1891, No. 11, The Mango Weevil (*Cryptorhynchus mangiferae*), pp. 45-46. Plate. (Taken from a paper by W. J. Simmons in the Journal of the Agricultural and Horticultural Society of India, Volume VIII, Part II, new series.)

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The geographical range of the pest under consideration is extensive. It is found in the Isle of France and in Madagascar, and it would be interesting to learn something about its ravages, and to ascertain when it was first observed, how supposed to be introduced, etc., in the islands named. It does not yet affect all the mango-producing districts of India, but its march is progressive. Restricted apparently at one time to Dacca and the Southeastern districts, Backergunge, Furridpore, etc., I learn it is working its way westward and northward, and throughout Bengal and the neighboring districts. An article on the subject will be found at page 558 of *Reis and Rayyet* for 1885, in which we are told that this insect-pest has invaded the Presidency, and that in the season of 1885 it showed itself in the well kept orchard of Kaly Kissen Tagore. I learn from a gentleman residing in Ballygunge that every tree in his garden is infected. *Reis and Rayyet* also informs us that Slyhet was formerly practically free from this circulio, two or three mangoes per 1,000 alone being tainted. During the last few years the pest has gained ground so rapidly in Sylhet that now not a single tree nor fruit is free.

ITS INTRODUCTION

The mango weevil is not recorded by Dr. R. C. L. Perkins in that part of Fauna Hawaiiensis, published in 1900, dealing with the family of beetles to which this species belongs. As the collection of the species therein recorded by Dr. Perkins ceased some two years previous to the above date, it is almost certain that the weevil of the mango has been introduced since 1898. It came from India, or possibly the Philippines, if it occurs in the latter country, since mangoes have been shipped to Hawaii from both places. The beetle was introduced either during the developmental period in the seeds or in the hibernated state in the soil about plants from the infested countries, or possibly even in packing or crevices of boxes containing plants.

ITS OCCURRENCE IN HAWAII

The mango weevil is first recorded from the Hawaiian Islands by the writer in August, 1905.[1] The first specimen observed was a pupa that Mr. J. E. Higgins discovered July 5, 1905, within the seed of a mango that he had collected at Mr. Allan Herbert's former place at Kalihi, Island of Oahu. Two days later the writer visited the district of Moanalua, this Island, and there found larvae, pupae and adults within the seeds of various varieties of mangoes. Mr. Donald MacIntyre, Superintendent of Moanalua Gardens, had not noticed the presence of the weevil in the seeds for the reason that for the past two years he had not removed the husks from the seeds before planting them. For seven years previously, however, Mr. MacIntyre informed the writer that he had practiced the removal of all husks before planting seeds in the nursery and it is reasonable to suppose from this that the weevil made its advent into the Moanalua Gardens not earlier than 1903. Inquiry of Mr. David Haughs, Mr. J. E. Higgins and Mr. G. P. Wilder, all prominently interested in mango culture, brought out the information that the weevil had not been observed in Honolulu up to the summer of 1905. Mr. Haughs, in his connection with the Territorial Government Nursery, has planted mango seeds for many years and has practiced removing the husks from the seeds for horticultural reasons. The distribution last year, then, so far as is known, was confined to this Island (Oahu) and extended from Kalihi to Moanalua.

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[1] Pacific Commercial Advertiser, Honolulu, August 11, 1905, p. 3, and The Hawaiian Forester and Agriculturist, Vol. II, No. 8, (August), Honolulu, 1905, pp. 231-233.

In July, 1906, Mr. Alexander Craw in a report as Superintendent of Entomology to the Territorial Board of Commissioners of Agriculture and Forestry, recorded the mango weevil as having been found this season from Palama, Honolulu, to Pearl City.[1]

Mr. Otto Swezey informed the writer that he found specimens of the larvae, pupae and adults within the seeds of ripe fallen mangoes on Gulick avenue, Honolulu, on June 12th, 1906, and Dr. R. C. L. Perkins likewise states that he had found mangoes infested with the beetle this season at his home in Nuuanu Valley. The beetle is seen to have extended its distribution over a

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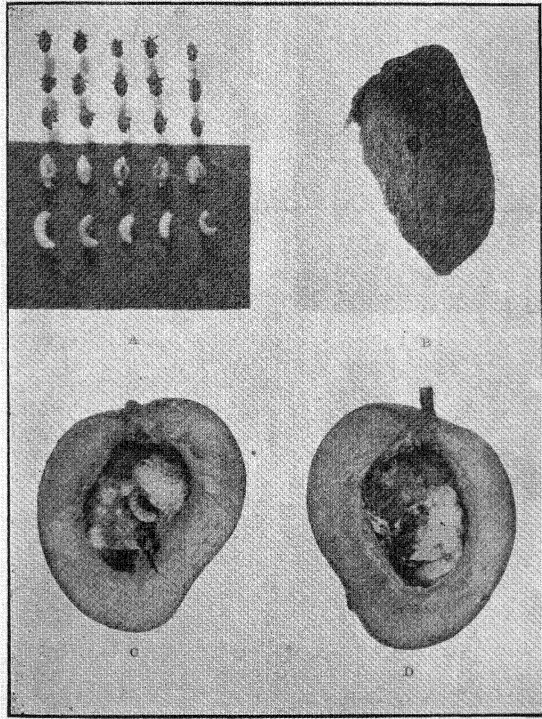
[1] Hawaiian Forester and Agriculturist, Vol. III, No. 7, (July), Honolulu, 1906, pp. 198-199.



THE MANGO WEEVIL (*Cryptorhynchus mangiferae*) AND ITS INJURY.

Explanation of Plate: A, Larvae, pupae and adults of the weevil, slightly reduced. B, a seed showing exit of adult weevil after completing development within. C, half a mango with fully developed larva within newly prepared pupal cell. D, half of mango showing destruction to seed. (Photographs by the author.)

considerable area during the past year. It is known that mangoes were shipped to the Island of Maui last year from the infested district (before the presence of the weevil had been discovered), and it is probable that the weevil has been carried to that island. To date the reported distribution is confined to the Island of Oahu and extends from Nuuanu Valley, Honolulu, in the Ewa direction to Pearl City.

THE WEEVIL AND ITS LIFE-CYCLE (See Plate I, A.)

As a beetle, the mango weevil has a thick pair of wing-covers which, when folded together at rest, give the body the appearance of a shell. The wing-covers are much rounded and extremely hard. As a weevil, the head is prolonged in front into a beak or rostrum, bearing the antennae on its sides and the modified mouth-parts at the extreme end. The mouth-parts are formed for gnawing. In the mango weevil, the beak is short and thick and when at rest is turned back beneath the thorax in a groove terminating between the first pair of legs. The adult weevil varied from 1/4 of an inch to 5/16 of an inch in length in the specimens measured. When newly developed, the adult is a whitish pink in color, but soon changes to a dark brown with yellowish markings.

The beetle feigns death on being disturbed and drops to the ground with the head drawn well under the thorax and the legs folded beneath the body. Its protective resemblance to coarse earth and debris is particularly noticeable. Nothing has been observed in regard to the food habits of the adult.

The eggs of the mango weevil were found on mangoes from one-half to three-fourths fully grown, situated alongside a slight incision on the rind. The writer has not observed egg-laying or carefully noted the habits of the weevil as regards oviposition, but is inclined to think that the eggs in the instances seen were probably placed within the incision or cavity and later forced out by the exudation of juice, an amount of which in a dried condition enveloped them.

The larvae in appearance are, generally speaking, like the sugar-cane borer (the larva of *Sphenophorus obscurus*), that is, footless, "fleshy" grubs, light in color, with a dark head. The entire development after hatching from the egg is undergone within the seed. When fully developed, the larva constructs a pupal cell, surrounded simply by the excrement, within the tunnel formed by feeding, and transforms to the pupa. The inactive pupa is perfectly white in color with the developing head, legs, wings and body-parts plainly indicated.

The length of the various stages in the life-cycle of the mango weevil can be given only approximately from this year's notes. In the locality under observation, the adults became active about May 16th. The first newly hatched larvae were to be seen from May 28th on. Pupae were found on June 27th and adults on July 3rd. The first adult weevils seen of this year's brood were those reported by Mr. Swezey, taken by him June 12th on Gulick avenue, Honolulu. The mango crop in that locality, however, was nearly a month earlier than at the place where the above notes were taken. The life-cycle appears to be approximately 40 days in length and there can be but one brood a year.

ITS HIBERNATION

The various stages of the mango weevil were found last season all through July, following the discovery of the insect. Not more than one specimen was found in any one seed. During August, refuse seeds and the seeds of fallen mangoes contained some pupae and many adults. As late as September 11th the seeds beneath trees in the infested district contained adults but in no great numbers. It appeared that the beetles remained in the seeds for a time after completing their full development. On the last date mentioned, September 11th, three living adults were removed from as many seeds and placed in a tightly corked phial beneath a plug of cotton. On October 13th all of these specimens were living. The writer was absent from the Territory for nearly a month, but upon his return, November 15th, one weevil had died. Another weevil failed to show signs of life on January 3rd. The third specimen lived until February 10th. From

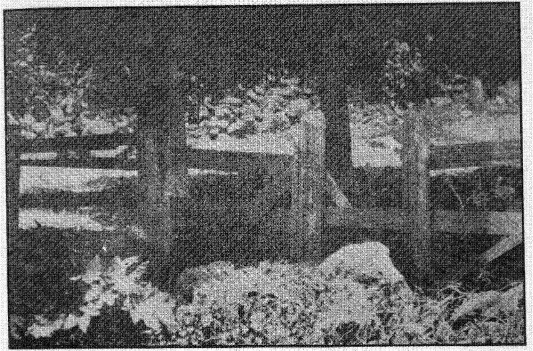


Fig. 1.—A fence beneath mango trees that contained numbers of hibernated weevils in cracks, crevices and behind the boards where nailed to the posts. Hundreds were found in one board that had been previously riddled by termites, the tunnels of the latter affording an excellent place of concealment. (Photograph by the author.)

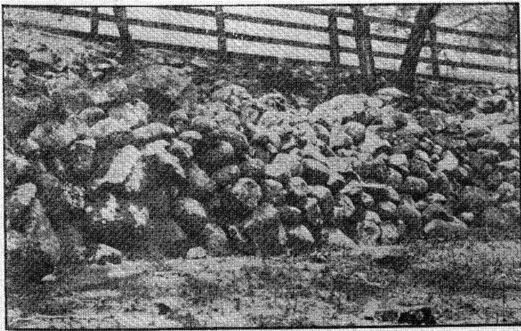


Fig. 2.—A stone wall beneath mango trees in which hibernated weevils where found in large numbers. (Photograph by the author.)

PLACES IN WHICH HIBERNATED WEEVILS ARE FOUND.

these observations it was evident that the insect could pass a considerable period in an inactive state. The same date the above experiments were begun, a quantity of seeds from fallen mangoes from the infested district was placed in a breeding cage. The idea was to determine the length of time the adults would continue to appear from within the seeds. After making an exit through the husks the beetles showed no tendency to remain within the seeds. Apparently nearly all the weevils had left; however, on October 4th, four specimens were found on the wire screen above the seeds. One specimen appeared on October 15th and on November 16th the seeds were all taken out and examined and two dead specimens were found out of the seeds on the floor of the breeding cage, having issued from the seeds between October 15th and the last date mentioned during the absence of the writer. No weevils were contained in the remaining seeds.

At this time a visit was made to the infested district and all traces of the weevil had disappeared. Diligent search failed to show where they were until January 30th when the writer found them by the hundreds in the crevices of an old board fence and stone wall beneath a group of neglected mango trees in a deserted kuleana in Moanalua Valley. (See Plate II.) The writer believes that the larger portion of the weevils went into hibernating quarters in similar places during the latter part of August and the first part of September. The weevils were found in a state of hibernation in that particular locality up to May 16th. An active beetle was observed on the foliage of a nearby mango tree on that date. At this time the fruit crop was about one-half grown.

ITS ENTRANCE TO THE SEED

From May 16th on, hundreds of mangoes were sectioned in halves to find, if possible, evidences of the larvae within the seeds. May 28th one newly developed larva was found within the seed of a nearly full-grown mango. In several instances thereafter newly hatched larvae were found within the seed and a faint, irregular discolored line or track leading from the tiny burrow within the seeds through the husk and into the flesh, indicated the mode of entrance. It is to be seen from this that the fruit is infested rather late in its development. The larva, apparently, on hatching from the egg on the rind or in the flesh, burrows at once to the seed within the husk and the resulting injury to the tissues of the fruit is so slight that soon all evidences of the means of entrance become effaced.

ITS INJURY (See Plate I, B, C, and D.)

The mango weevil is not known to attack any other fruit. Its injury to the mango is primarily the destruction of the seed. The incisions in the rind do, of course, blemish the fruit and offer places of infection for the germs of decay. In the first lot of mangoes examined on July 7, 1905, it was estimated that about 60 per cent. were infested, that is, out of 44 seeds examined, 28 contained either the larval, pupal, or adult, weevil. The inspection of another lot of seeds six days later resulted as follows, 16 seeds each of the "Number 9," the Chutney and the so-called "Hawaiian" variety being taken: Of the Number 9, 5 were infested; of the Chutney, 10 were infested; and of the Hawaiian, 8 were infested.

The following results were obtained from seeds planted in seed-beds: Twelve seeds each of the Chutney and "Number 1" were selected at random, and of the former, 10 were infested. Of the latter, 3 were infested. All of the infested seeds had failed to germinate. In both instances the Chutney variety showed the largest number of infested seeds.

The injury is much greater this season than last. The writer estimates that fully 80 to 90 per cent. of the mangoes are infested this year in what was considered the infested district last year. Where the weevil occurs for the first time this season, the infection is not so great. Not more than a single specimen was observed within a seed last year. As many as four larvae have been found within a single seed this season and two and three specimens within a seed are common. Where as many as three or four larvae occur within one seed, the resulting decay from the excrement and seed extends through the husk, in some instances, to the flesh. Some growers are of the opinion that the work of the weevil hastens the maturity of the infected fruit and increases the percent. of fallen mangoes.

ITS NATURAL ENEMIES

No parasitic or predaceous enemies of the mango weevil have been observed. The writer believes, however, that many of the hibernated weevils are destroyed by lizards and centipedes.

ITS CONTROL

Natural Control: Since the mango weevil is a special feeder on the seed of the mango, its numbers in any particular season are in direct proportion to the size of the mango crop for that season. That is, when the mangoes are abundant, the brood of weevils arising from the fruit will also be large in numbers. Any natural condition of climate or disease that affects the mango crop will likewise reduce the numbers of the mango weevil.

Direct Measures: The fact that the weevil during its entire development is within the seed renders the use of any insecticide impossible in combating the pest. Since also there is practically no exterior evidence that the fruit is infested, little can be done in the destruction of infested fruit during the growth of the crop.

The destruction of all fallen mangoes and refuse seeds will be quite effective for the reason that the adult beetle does not leave the seed until some time after the maturity of the fruit.

The burning of all refuse about the mango trees during the months from October to March would destroy many of the hibernated weevils.

To deprive the mango weevil of its food in any particular locality for two seasons would mean its extermination in that locality, and could re-invasion be prevented, it would further mean freedom from injury to future crops. An act worthy of the attempt would be to destroy for a period of two years all the fruit in the infested district after first making a careful survey of the distribution of the weevil. Neglected trees in deserted places and along the wayside could be cut down. All the common varieties could be cut back for in-arching or grafting with the finer varieties. The finer varieties, of which not a great number are under bearing, could be allowed to fruit and the fruit or refuse seeds destroyed. Certain trees should be left to fruit throughout the infested district to act as "bait" for the weevils. These trees should be under the control of inspectors and the fruit gathered and destroyed after the weevils of the previous season's brood had completed copulation and oviposition.

The limited time of the writer has been devoted almost entirely to the life-cycle and habits of the pest, necessary information on which to base methods of control, and concerning which practically nothing could be found. Another season's observation will be necessary to advance more definite advice on the control of this insect enemy of the mango.

Honolulu, H. T., August 14, 1906.

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H. A. MORGAN,
Knoxville, Tenn.
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Press Bul. 20, Issued July 25, 1907.

Hawaii Agricultural Experiment Station,

HONOLULU

J. G. SMITH, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 20.

THE INTRODUCTION OF TOP-MINNOWS
(Natural Enemies of Mosquitoes)
INTO THE HAWAIIAN ISLANDS.

IN COÖPERATION WITH THE BOARD OF HEALTH, TERRITORY OF HAWAII AND LELAND STANFORD JUNIOR UNIVERSITY.

BY D. L. VAN DINE,

Entomologist, Hawaii Agricultural Experiment Station, United States Department of Agriculture.

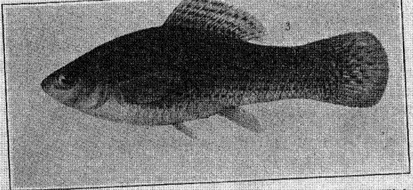

Fig. 1.—Top-Minnow, *Mollienesia latipinna*. (U. S. Fish Commission.)

In December, 1902, a survey of Honolulu and vicinity was begun to determine the character and location of the bodies of water responsible for the great numbers of mosquitoes that were common at nearly all seasons of the year. The places in which mosquitoes were found to breed can be classed under two general heads: (1) Such collections as in containers for storing water (tubs, barrels, troughs, water-tanks, etc.); cesspools; surface sewers and the catch-basins; discarded tins, bottles, and cans in vacant lots and on rubbish heaps; neglected gutters and defective plumbing; and vessels holding water in and about dwellings and out-houses (flower vases, drinking cans in chicken yards, containers under table legs and flower pots, etc.); and (2) the collections of water as taro-patches; rice fields; reservoirs; irrigation ditches; swamps; closed pools; ponds; temporary pools formed by storm water on the lower levels; and pools in the beds of streams during the dry seasons.

The breeding places included in the first class are responsible for the larger part of the number of mosquitoes in any locality. They are entirely responsible for the mosquitoes in the business section of the city and in those residential portions that are at any distance removed from the collections of water enumerated in the second class of breeding places. To obtain relief from the mosquitoes that breed in the collections of water of the first class it is demanded that systematic inspection work be carried on continuously throughout the infested district. This inspection must be followed by active measures of prevention, that is, preventing the development of the mosquito larvae or wrigglers in any body of water discovered that is capable of acting as a breeding place. The preventive work implies screening, draining, oiling, hauling away tins, bottles, broken crockery, etc., and periodically emptying containers used for watering stock, or holding plants or flowers about the house. Emphasis is given this phase of mosquito control at this time to prevent a misconception on the part of the people of this Territory in regard to the amount of relief to be expected from the establishment of the top-minnows in local waters.

The collections of water comprising the second class cannot always be dealt with directly without a great expenditure of money in drainage work or seriously interrupting such agricultural operations as rice and taro culture. It is obvious, then, that while any natural check or enemy of mosquitoes is desirable, it is particularly to be desired in the case of mosquitoes developing in these bodies of water. Previous to the successful introduction and establishment of the top-minnows in Hawaii no effective enemies of mosquitoes occurred.[1] The dragon-flies or mosquito-hawks and the gold-fish were their only important enemies but neither are special mosquito feeders, although the winged dragon-fly devours many adult mosquitoes in the air and the gold-fish feeds on the larvae to a certain extent in the water, especially when confined in a fountain, lily-pond, or aquarium.

The question of introducing the top-minnows into Hawaii was first considered in the early part of 1903, these fish having been reported as effective enemies of mosquito wrigglers elsewhere.[2] Dr. David Starr Jordan, to whom the problem was referred, replied that these fish had never been transported such a distance but, while the whole undertaking would be an experiment, the fish were extremely hardy and the greatest consideration would be the cost of the work. Because of the cost this phase of mosquito control did not receive further notice at that time.

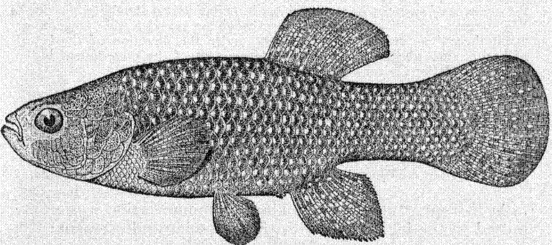

Fig. 2.—Top-Minnow, *Fundulus grandis*. Enlarged. (U. S. Fish Commission.)

During 1904 a Citizens' Mosquito Campaign Committee was organized in Honolulu and this body was instrumental in providing the means for the introduction of the fish. The writer had an opportunity to discuss the subject personally with Dr. Jordan and in the interview Dr. Jordan offered to send an expert from Stanford University to collect the fish and bring them to Hawaii on condition that the Territory pay simply the expenses of the undertaking. This offer was fully appreciated by the Territory. On a recommendation from the Citizens' Mosquito Committee, the Governor presented an item of $1500 to the Legislature of 1905 to cover the expenses of the experiment. The communications on the subject were as follows:

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[1] The species introduced were *Mollienesia latipinna Fundulus grandis*, and *Gambusia affinis* of the family *Poeciliudae* collected and transported to the Islands from Seabrook near Galveston, Texas, by Mr. Alvin Seale. See figures number 1, 2, and 3.

[2] L. O. Howard. Mosquitoes, New York, 1901.

(Letter from the Citizens' Mosquito Committee to the Governor.)

Honolulu, Hawaii, March 12, 1905.

Hon. George R. Carter,
Governor of the Territory of Hawaii, Honolulu.

Sir: Dr. David Starr Jordan, of Stanford University, having offered to send an expert of that institution to collect for these islands certain fish of the Southern States and Mexico, at present entirely unrepresented here, that feed upon the larvæ of mosquitoes, providing the Territory pay the expenses of such trip, the undersigned, at your request, beg to say that for the expense of such a trip a sum of not less than $1,500 should be provided. We suggest that, if appropriated for the above purpose, this sum, or as much thereof as is necessary, be spent under the direction of the board of health, since the president of that department of the government is the chairman of the Citizens' Mosquito Committee.

Very respectfully yours,
CHAS. B. COOPER, M. D.,
Chairman Legislative Committee.
D. L. VAN DINE,
Chairman Advisory Committee.
Representing the Citizens' Mosquito Committee of Honolulu.

At the opportune time the above communication was transmitted to the legislature with the following indorsement:

(Letter of May 10, 1905, from Governor Carter to the legislature.)
To the Legislature of the Territory of Hawaii:

Herewith, I transmit for your consideration copy of a letter of March 12, containing a proposal made by Dr. David Starr Jordan, of Stanford University, to provide an expert, with the necessary apparatus, to undertake the importation into these islands of a certain small and vigorous fish found in Mexico that feeds on the larvæ of the mosquito, provided the Territory simply pays the expense of such an undertaking.

You are aware that the only fish we have at present exclusively occupying our fresh waters is a species of mud fish, commonly known as the oopu, and the gold fish. You are also aware that there is known to exist here the species of mosquito which carries the germs of yellow fever, which, fortunately for us, has not as yet been inoculated, but with the completion of the Panama Canal it will only be a question of time before cases of this or some other disease will reach this port. Every interest in the Territory would be advanced if this mosquito could in some way be entirely eradicated, or at least reduced to the smallest possible number.

G. R. CARTER,
Governor.

The subject was referred to the health committee of the House. The committee reported favorably and the item ($1500.) was included in the general expense bill of the Territorial Board of Health for disbursement. This money was not available until July 1st, but as soon as possible thereafter an advance was sent to Mr. Alvin Seale at Stanford University, the man selected by Dr. Jordan to carry on the experiment.

The following report by Mr. Seale covers the work of collecting the fish and their transportation to Hawaii:

REPORT OF MR. SEALE.

Honolulu, Hawaii, September 23, 1905.

Mr. D. L. Van Dine,
Entomologist, U. S. Experiment Station,
Honolulu, H. T.

Dear Sir:—In accordance with the following letter to yourself from Dr. David Starr Jordan, I was chosen to attempt the introduction of "top-minnows" or "killifish" into the Hawaiian Islands for the purpose of destroying the larvae of mosquitoes:

LELAND STANFORD JUNIOR UNIVERSITY.

Office of the President.

Stanford University, Cal., April 18, 1905.

Mr. D. L. Van Dine,
United States Experiment Station,
Honolulu, Hawaii.

Dear Sir:—The best place to collect the fishes which you want would doubtless be in Louisiana. It would probably take no longer time to bring them from there than from any other places nearer. Perhaps an equally good place would be Tampico, on the edge of Mexico. You understand that this would necessarily be an experiment. These little fishes feed freely on mosquitoes. Some live in brackish water, some in fresh water, and all of them are very hardy. But no one has ever tried to transplant any of them, and the whole thing might turn out, for some reason or other, to be a failure. Especially one would need to experiment on feeding the little fishes during their transportation. The genera which I would recommend are Mollienesia, Adinia, Gambusia, and Fundulus. Some of these are viviparous, others lay eggs. Whoever undertakes this should give a good deal of attention to the question of feeding the little fishes, and for this purpose perhaps a tank breeding mosquitoes would be as good as anything. The best time to undertake it would be about the 1st of June. I will select some one as soon as I hear from you.

Very truly yours,
DAVID S. JORDAN.

On receipt of yours of July 11, 1905, with the advance of $500 of the Territorial appropriation covering the expenses of this undertaking, I started from Stanford University to the Southern United States. It was my intention to secure the top-minnows at or near New Orleans, but the rigid quarantine in operation in Louisiana prevented my carrying out this plan. Seabrook, near Galveston, Texas, was then selected as the next place most available. At Seabrook I found the family of top-minnows, *Poeciliidae*, in large numbers. They were swarming in all the stagnant waters at sea-level as well as in various ditches, ponds, and standing pools. Mosquitoes are very plentiful in and about Seabrook, but after a study of the situation I am convinced that their source is not the bodies of water containing these fish but rather temporary and artificial breeding places, such as closed pools, tubs, tin cans, and other refuse which are not accessible to these fish.

As per his letter to you, Dr. Jordan recommended the following genera: *Mollienesia, Adinia, Gambusia* and *Fundulus*. These are all members of the single family Pœciliidae or top-minnows. I first made a careful examination of a number of the stomachs freshly taken from members of the above genera. The stomach-contents was found to consist largely of larvae of various insects, including those of mosquitoes; egg-masses of mosquitoes; minute crustaceæ and some vegetation. The results showed that Gambusia were the best insect feeders. Of 100 stomachs of this genus examined all contained many insect larvae and eggs among which I noticed especially numerous egg-masses of the mosquito. However, Mollienesia, Fundulus and Gambusia differed slightly in regard to their capacity for the various insect larvae and the difference was probably due to the different food localities. The temperature of the water in and about Seabrook in which these fish were found ranged from 74° to 87°.

It now remained to determine under what conditions the fishes could be most successfully transported to Hawaii. Six ordinary ten-gallon milk cans were prepared by puncturing the covers with numerous holes and placing the cans in bran sacks, the intervening space being tightly packed with Spanish moss. This served to keep the water at an even temperature. Two hundred fish were placed in each can. The following morning so many were dead that it was evident the cans were overcrowded and I reduced the numbers to one hundred.

Experiments were conducted as follows:

Can No. 1. Allowed to stand undisturbed. Water unchanged and unaerated. Temperature normal. The first morning six fish were dead. The second day, two died. The third day the fish were perfectly lively and were taking food freely. The fifth day five died and by the eighth twenty had died. The experiment was not carried further.

Can No. 2. Water changed once each day. Temperature normal (ranged from 74° to 78°). During the first three days there were four deaths. The eighth day two died. After this time there were no more deaths. Fish fed freely on mosquito larvae, and prepared fish food.

Can No. 3. Water changed twice each day. Temperature normal. Three deaths the first night. After this time there were no more deaths. Fish fed freely on mosquito larvae and prepared fish food.

Can No. 4. Water changed every two days. Temperature normal. Five deaths the first three days, after which no fish died. Fish fed freely, keeping constantly at top of the water.

Can No. 5. Water slowly and very gradually reduced in temperature to 40°. Fish would not feed at the end of six days. During this time eighteen had died. Experiment discontinued.

Can No. 6. Water reduced slowly to freezing point, then can packed in ice. At the end of six days all but three of the fish were dead. Experiment discontinued.

The above experiments demonstrated that the fish should be transported in water at the normal temperature and gave the necessary information in regard to the frequency of changing the water.

The three most abundant species, *Gambusia affinis, Fundulus grandis* and *Mollienesia latipinna,'* were collected and approximately seventy-five placed in each can. On Sept. 4, 1905, I left Seabrook, Texas, on the long journey to Honolulu. A 20-gallon tin tank was taken along as a supply reservoir.

The following routine work was observed during the entire trip: At 8 a. m. the fishes were fed sparingly on prepared fish food, finely ground liver or hard boiled eggs; at 9:30 half the water in each can was siphoned off from the bottom, thus cleaning out the cans and removing all uneaten food and excrement, and an equal amount of fresh water added; at noon the cans were all aerated by means of a large bicycle-pump, a sponge being tied over the end of the hose to separate the air into fine particles; at 4 p. m. two gallons of water were siphoned off from the bottom and two gallons of fresh water were put in; just before retiring the cans were again aerated by means of the air-pump.

At each place en route where the water was changed it was first tested by placing two fish in a bucket containing the new water at the proper temperature. At El Paso, Texas, only, did the water kill the fish thus treated. After ten minutes the two fish were dead, probably due to the alkali it contained. The water at Los Angeles was good as also the San Francisco water, which was used from the latter place to Honolulu, an abundant supply being carried on the steamer. The water used from El Paso to Los Angeles was taken from the supply tank, filled at San Antonio, Texas.

Twelve fish died between Galveston and San Francisco and only fifteen between San Francisco and Honolulu. The fish were landed in Honolulu from the S. S. "Alameda" on September 15, 1905, the trip from Texas occupying 12 days and 27 of the approximate 450 fish were lost.

The fish were in fine condition on arrival and as prearranged by yourself were placed in the breeding ponds prepared for them. The temperature of the water about Honolulu is almost identical with that where the fish were collected, and the appearance of the fish at this writing indicates that they should thrive on the Islands. The fish should be confined in the present breeding ponds, where they can be prevented from going out to sea or falling prey to other fish until their increased numbers permit general distribution to other localities in the group.

Very truly yours,
ALVIN SEALE,
Assistant, U. S. Fish Commission.

Upon the arrival of the steamer the fish were taken at once to Moanalua near Honolulu where, through the courtesy of Hon. S. M. Damon, a series of four ponds had been prepared for their reception and breeding. An irrigation ditch led clear water to the ponds through a gate-way guarded by wire cloth of a fine mesh. The outlet was guarded in a similar manner. The water was allowed to circulate through three of the ponds but no outlet was provided for the fourth in order that the water might remain standing. Two of the ponds were about two feet in depth with one free from vegetation and two were from two to six inches in depth, with one also free from vegetation. These varying conditions represented somewhat the shallow waters of the Islands as regards depth, temperature, presence or absence of vegetation and standing or running water. About equal numbers of the fish were placed in each of the four ponds.

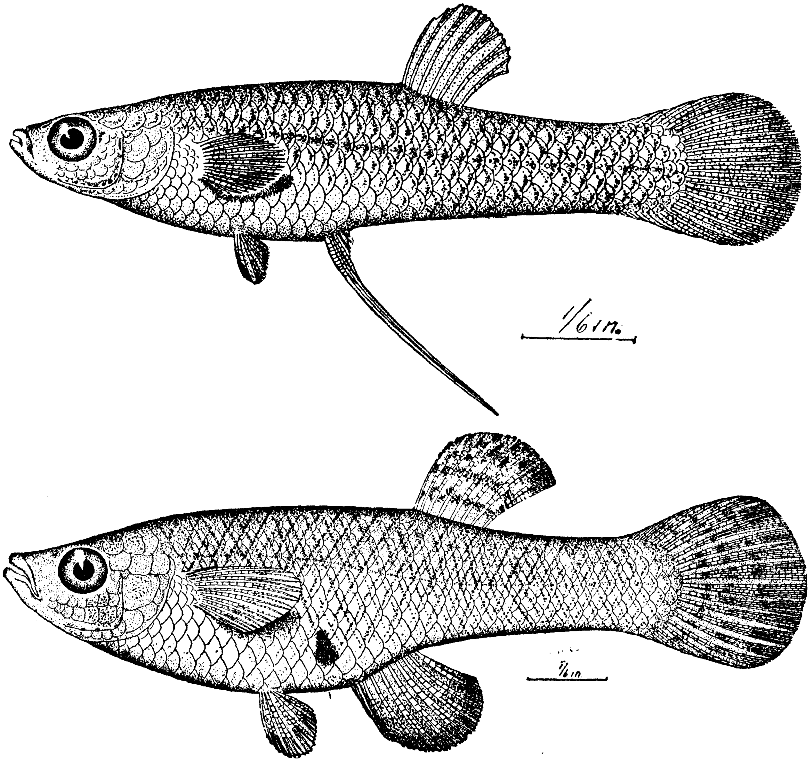

Fig. 3.—Top-Minnow, *Gambusia affinis*. Male above, female below. Enlarged. (U. S. Fish Commission.)

The fish thrived in all of the ponds almost equally well, the main advantages of their confinement being the prevention of their being carried out to sea by a freshet and the protection from other predaceous fish.[3] It was determined, however, by observation at the ponds and in other locations where the top-minnows were liberated later that they thrived best in shallow, standing water at a temperature ranging from 76° to 82° F. The fish show no inclination to go out to sea and avoid the deep water, lessening the probability of their being eaten by the larger predaceous fish.

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[3] Dr. Jordan informed the writer that the Hawaiian fish likely to prey upon the top-minnows were *Sphyracna snodgrassi* (Kaku) in the mullet ponds, Elops (Awa-Aua), and Kuhlia (Aholehole).

They have multiplied rapidly and from the few hundred introduced, several hundred thousand have been bred and distributed. Where they occur they effectively clear the water of the mosquito larvae, feeding likewise on the egg-masses of *Culex pipiens* on the surface. In the absence of mosquito larvae or eggs the top-minnows feed upon the smaller aquatic insects of other species, as the nymphs of the water boatman, *Corixa blackburni*, eating also various small insects that fall into the water and are drowned. In an aquarium the larger fish have been observed making way with the very small of their own kind in the absence of other food.

Under the direction of the writer, the Territorial Board of Health has made the following distribution of the top-minnows from the funds appropriated for their introduction and distribution by the Legislature:

Island of Oahu: Honolulu and vicinity generally, Aiea, Pearl City, Waialua, Maunawai, Wahiawa and Waimanalo.

Island of Hawaii: Hilo and vicinity, and Paauhau.

Island of Maui: Kahului, Wailuku and Lahaina.

Island of Molokai: Kalaupapa.

Island of Kauai: Lihue, Eleele, and Waimea.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 21.

Fruit Marketing Investigations in 1907.

BY J. E. HIGGINS,

Horticulturist, Hawaii Experiment Station, United States Department of Agriculture.

INTRODUCTION.

Fruit production is destined to become one of Hawaii's most important industries. Already pineapple growing has assumed very considerable proportions, and there are today between two thousand and three thousand acres under successful pineapple cultivation, where a few years ago the land was thought unfit for any purpose other than grazing. The pineapple area is rapidly increasing and conservative men believe that the industry is as yet in its infancy.

Other fruits, it is believed, will repeat the history of the pineapple in Hawaii. Together with the soil and moisture requirements, the absolute freedom from frost renders this group of islands peculiarly adapted to the growth of tropical and subtropical fruits. Some of these fruits such as the avocado, the mango and the papaia in their present state of semi-cultivation or absolute neglect give great promise of results under the new horticulture which is beginning in Hawaii.

To ascertain the best methods of marketing, including every step in the process from the gathering of the fruit in the field, to its sale in the market, is quite as important in any fruit industry as the knowledge of production. To determine some of the important factors in marketing Hawaiian fruits, the Hawaii Experiment Station has undertaken a series of experiments which have now covered about four years. The report of this work to the close of the season of 1906 has been published in Bulletin No. 14. This paper presents the results of experiments and observations in 1907 so far as they are of immediate practical application.

On July 24 there was shipped from Honolulu to San Francisco a consignment of about 12 tons of pineapples, 1300 avocados and 200 papaias. These were under the direction of the horticulturist of the Station, who personally accompanied the shipment. A part of the pineapples were trans-shipped by water to Los Angeles. There and in San Francisco careful examination was made of the fruits in each crate, although in Los Angeles it was not possible to personally supervise the work.

Cable advices regarding the results of different methods of handling and packing were forwarded to the experiment station, and preparations were made for a shipment to Chicago of a car load of pineapples and avocados. The date of sailing was August 14 and that of arrival in San Francisco, August 21. This fruit was examined and such of the pineapples as appeared to be in condition for trans-shipment, were sorted, repacked, placed in a refrigerated car and forwarded to Chicago, by way of Ogden leaving August 22, and arriving in Chicago, August 31. All the avocados were placed in the car without repacking. The car was pre-iced on the afternoon of August 21. September 1, being Sunday, and September 2 falling on Labor Day, it was not possible to remove the fruit from the car until September 3. On the third day a careful examination was made of the

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avocados and pineapples. The avocados were in good condition for immediate consumption, but were not so firm as they should be for the market. Had they been perfectly hard when taken from the steamer, it is believed they would have arrived in the same condition in Chicago.

The pineapples opened up in most excellent condition. The loss was less than one per cent. It was reported that some of the fruits showed more or less discoloration in ripening. This, however, has been noticed repeatedly on fruits shipped with refrigeration and without to San Francisco and other points. The outcome of this trial shipment by rail strongly suggests that it will be no more difficult to place Hawaiian pineapples in the interior markets than in the markets of the Pacific Coast.

GENERAL.

For convenience and to avoid needless repetition, subjects relating to transportation, markets and organization for marketing purposes, may be discussed in general.

TRANSPORTATION.

By Land. Until the present time there has been practically no freight transportation of Hawaiian fruits by rail. A few express shipments have been sent to inland cities, and by water freight Hawaiian pineapples have reached the chief markets on the Pacific Coast. One of the obstacles in the way of shipments by rail has been the high freight tariff. The railroads subject to the Inter-State Commerce Commission have made a tariff schedule on "deciduous fruits," and other tariffs on citrus fruits. Though the term "deciduous fruits" is of rather loose application, Hawaiian pineapples and many other tropical fruits could not well be classified here. In preparation, therefore, for the experimental shipment by rail to Chicago, this subject of freight rates on tropical fruits was taken up with the railroads. Permission was received by them from the Inter-State Commerce Commission to announce a regular tariff on "tropical fruits," identical with that for "deciduous fruits." The tariff sheet now reads, "Rates on Deciduous and Tropical Fruits."

These rates are as follows:

TO	In Carloads of not less than 24,000 lbs. PER 100 LBS.
Colorado Common Points	$ 1.15
Missouri River Common and intermediate points and points west thereof to which Missouri River Common and intermediate rates are authorized to apply	1.15
Mississippi River Common Points	1.15
Chicago and Common Points	1.15
Cincinnati, Detroit and Common Points	1.40
Pittsburg, Buffalo and Common Points, including points in Canada taking Toronto rates, as shown on pages 10 to 21 of the tariff	1.40
New York, Philadelphia, Baltimore, and Common Points, including points in Canada taking Montreal rates as shown on pages 10 to 21 of the tariff	1.45
Boston and Common Points, including points in Canada taking Sherbrooke rates, as shown on pages 10 to 21 of the tariff	1.45

This practically opens the way for carload trans-continental shipments. Hawaii can now take advantage of all the facilities for shipment offered to the fruit growers of California. These facilities, which have been gained by the California shippers, through long and strenuous experiences, are practically the free gift to the shippers from Hawaii. During the whole of the fruit season special fruit trains leave daily for Eastern points. These are hastened through to destinations as rapidly as possible, the time required from San Francisco to Chicago being scheduled at eight days. Cars are kept iced throughout their journey and the shipper is permitted to give his own instructions regarding the opening or closing of the ventilators. The railroads issue a sheet for the convenience of the shipper which is as follows;

REQUEST TO VENTILATE PERISHABLE FREIGHT.

. . . . 190 . .

To Agent,

. . . .

. . . .

We have this day delivered to you for transportation the following perishable freight . . . .

. . . .

Car number . . . .

Initial . . . .

Destination . . . .

Consignee . . . .

Keep ventilators open to destination . . . .

Keep ventilators open to . . . .

Keep ventilators closed, to destination . . . .

Close ventilators at . . . .

Open side doors for ventilation at . . . .

It is understood as between shipper and carrier that the carrier undertakes to comply with above request only as accommodation to and in the interest of shipper, and in so doing does not assume any risk for loss or damage to said property.

. . . . **Shipper.**

Note:—In absence of specific instructions by shipper as to opening and closing ventilators, the carriers will **exercise their judgment,** at owners risk, and for information of railway employes only, **waybills will be stamped:**

"Put in ice plugs and close hatches when temperature falls below freezing. Open hatches and take out ice plugs immediately when temperature is above freezing."

MANNER OF PACKING THE CAR. It is important that a car should be properly packed in order to permit of the free circulation of air among the crates and, at the same time, to prevent shifting. In so long a haul with many stops and sudden jerks in switching, if the crates are not held firmly in position they would rapidly be broken and the fruit injured. Different methods of packing a car are in vogue with different kinds of fruits and different types of crates. Orange boxes for example, are usually stood on end and the dimensions are such that a given number will exactly occupy the floor space of the car. With other fruits such as grapes, the crates for which are flat, there is usually an open space in the center of the car where the crates must be braced to hold them in position. Circulation of air among the crates is provided for by placing small strips on the floor of the car and beneath each tier. There is also a large open space running lengthwise of the car, between each two rows of crates. Were it not for this arrangement it would be practically impossible to get the fruit in the center of the car refrigerated. What method of packing pineapple crates in a car will prove best is a matter which must yet be worked out, and will probably depend in part upon what type of crate is adopted. From the limited experience afforded by a single car, it would seem that the large sized crate in most common use in Hawaii should be placed on edge. A car would probably hold about 160 crates, which would represent about 24,000 lbs. or the minimum carload. This would be without overloading the car by placing the fruit too high. It is always customary to leave a large open space at the top, on an average perhaps about ¼ of the height of the car. The warm air rises to the highest point, and therefore fruit that occupies a position near the top of the car would receive very poor refrigeration. This arrangement of the crates allows for four rows on the floor with an air space next to the walls of the car and between the rows.

COST OF TRANSPORTATION. The expense involved in moving a carload of pineapples from the wharf in San Francisco to Chicago, including the cost of repacking, would be approximately as follows:

Freight	$ 276.00
Loading	1.50
Repacking at 20 cents per crate	32.00
Cartage, wharf to car	16.00
Icing charges	85.00
Total	$ 410.50

Taking the weight of a large crate of pineapples packed, as 150 pounds, which is believed to be about an average, approximately 78 per cent of the total weight would be fruit, and 22 per cent tare. In a 12 ton car there would be about 9.36 tons of fruit, The cost of moving a ton of *fruit* from the San Francisco wharf to Chicago would be, according to these figures, about $44.00. Figured per crate, the cost would be about $2.55.

TRANSPORTATION BY SEA. REFRIGERATION. There are two distinct methods of transportation, by ocean freight, the one involving refrigeration, the other ventilation. Such fruits as avocados, mangoes, and papaia demand refrigeration, while the pineapple may be shipped without it, and its use is not at all adapted to the banana. Although the volume of freight demanding refrigeration at the present time is very small, there can be no question that it will increase and that the shipment of refrigerated fruit will become an important industry. In the interests of those who are already shipping this class of perishable goods, and also in the interests of future development, it is opportune to give attention to the requirement of refrigeration in ocean transit.

The exact temperatures which are best adapted to the preservation of each species of tropical fruit has not yet been determined. This in itself is a line of work which would involve extended experiments and which cannot be carried out without larger expense than the Station has been able to afford. It has been found, however, that avocados and papaias are not injured by a temperature of about 40 degrees F., continued for several weeks. On the other hand, it has been found that holding the temperature of the refrigerated compartment at 50 degrees F., has resulted in the ripening of the fruit. Tentatively, therefore, it is recommended that steamships carrying avocados and papaias should hold the temperature between 40 and 45 degrees.

STEVING THE FRUIT TO PERMIT REFRIGERATION. It is important in stowing the crates to place them so that there can be a free circulation of air between and also beneath them. Some adaptation of the methods adopted in packing cars, as described above, should be followed by the steamship companies in their refrigerated compartments. It is almost impossible to refrigerate a solid and compact mass; and it is only by causing the cold air to pass to every part of the compartment that the fruit can be brought down to a low temperature. The temperature indicated by the thermometer within the compartment may be no index to the temperature of the fruit in the crates. It has been found in trans-continental shipments made for experimental purposes by the Division of Pomology of the U. S. Department of Agriculture, that even with the best arrangement of packages within the car, and with ample supplies of ice the temperature of the fruit in the center of an orange box remains for several days far above that of the atmospheric temperature within the car. After a compartment on steamship is filled with fruit it will require considerable time to get the temperature of the room to 40 degrees, and it must then be distinctly borne in mind that the fruit will be much later in assuming this temperature, even with the best methods of steving. With no care being taken to permit free circulation, the fruit farthest from the pipes and in the center of the crates may spoil before its heat has been removed. For these reasons it is eminently important that the engines should be working and the room brought to a low temperature before being opened to receive the cargo, and that it should remain open the shortest possible time. When the cargo is in place the doors should be opened as little as possible, should never be allowed to remain open, and every effort should be made to hold the temperature at a uniform degree.

Every steamship attempting to carry refrigerated tropical fruits should observe these general principles. Furthermore, every steamship which is expected to develope the fresh fruit industries of Hawaii should be equipped with at least a small compartment which can be used for the carrying of such fruits as require low temperatures for their preservation. Only in this way can these smaller industries be developed, for no one will plant and cultivate fruits with no means of getting them to market.

SHIPPING UNDER VENTILATION. The greatest present need in Hawaiian fruit transportation is ventilation. The results recorded in Bulletin No. 14 of this Station have been confirmed by the experiences of the past summer. The requirements as set forth therein for the shipment of fruit without refrigeration were as follows: First, ventilation; second, dryness; third, reasonably low temperatures; fourth, careful handling and steving. Few if any steamships at present in the trade can assure the shipper that his fruit will receive these requirements of safe shipping. Pineapples and bananas have been carried on deck on some of the steamers, covered with an awning and with tarpaulin on the sides. Strips of board placed beneath the crates, permit of ventilation beneath. By this means, in favorable weather, both bananas and pineapples arrive at their destination in good condition. In heavy storms it is not easy to keep the fruit dry. In cold weather fruit cannot be shipped in safety on deck. The ventilation supplied to the compartments below deck is insufficient unless some method of mechanically forced draught is adopted. The windsail when it can be used serves a valuable purpose, but its use is subject to the uncertainties of weather. There is no one factor that the development of the fresh pineapple shipping industry depends upon so much as this matter of properly equipped steamships for the trade. The fruit is already growing, is being put in the cans at a much lower value than could be realized on fresh fruit shipments, the markets are asking for the fruit and the railroads offer means of transportation after it has once reached the mainland. Provided with suitable ships, the export trade in fresh pineapples would well repay the cost incurred in equipment.

From the standpoint of the fresh fruit shipper it is far more important that ships should be regular and frequent, than that they should be large. If local capital is to own or control ships which will carry this class of fruit, it must be remembered that one large ship though it may or may not be better from the standpoint of passenger traffic, will certainly not meet the needs of fresh fruit shipping. Fruit that is too immature for shipping today may be too ripe two weeks hence. The boats should run as frequently as once in ten days at least, and with regularity. If the shipper cannot know, within a few hours, the time of sailing, he may either have his fruit stand in the heat awaiting the departure of the ship, or it may be too late to be taken on board.

CAREFUL HANDLING of the fruit whenever it is moved is of great importance. The steamship handles the fruit in loading and unloading. The method adopted in unloading, whereby the crates are allowed to slide down a chute, is capable of doing much damage. This is a convenient and easy method of unloading, but with the average man at the foot of the chute, every crate stops with a sudden jerk bruising many of the fruits within. It might be possible to arrange a chute so that the crate would slowly stop, but in actual practice, it is an exception, so far as the writer's observation goes, that a crate is stopped without a sudden jar. In loading, if the crates are taken on board in a sling, a frame should be arranged so that the ropes will not bind against the outer crates and bruise the fruits within. It is a common practice in carrying crates to allow them to fall two or three inches when setting them down. This is true not only at the steamer but among all those who handle the crates. The practice must be avoided or bruising will certainly follow.

ORGANIZATION FOR MARKETING.

Of equal importance with transportation facilities, is the organization of the growers and shippers into a co-operative marketing concern. The success of co-operative marketing elsewhere and the failure of other methods which has been amply demonstrated in Hawaii, should be sufficient argument to lead all those interested in marketing fresh fruits to cooperate in a marketing organization. In fact, no large fresh fruit trade is likely to be built up except through some strong central organization of the shippers, or the formation of an independent marketing company who will buy the fruit for shipment. The latter will be the result if the growers fail to organize themselves. Such a company will buy the fruit at canning prices and ship them as green fruit, and thus the profits of fresh fruit marketing will pass from the grower. The need of organization has been set forth already in Bulletin No. 14 of this Station, and it is only necessary to say here that the observations of the more recent study of the markets has strengthened the conclusions presented therein.

The marketing organization should be represented in Honolulu and all points in the Territory from which direct shipments are made. It is also equally important that at least one man should represent the shippers in San Francisco, and the business would certainly demand in the near future that other representatives be placed in the different markets to be reached. Every agent should be on salary, with no commissions, and should not engage in the selling of other fruit. There should be a man in San Francisco to look after the interests of Hawaiian shippers, to receive, care for, and trans-ship fruit. This is all the more true since much of the fruit would be better for repacking before trans-shipment.

The local agent at the shipping point should receive the fruit, should see that it is handled with utmost care by the transfer and steamship companies, while the agent at San Francisco or other port, should be present to receive the fruit and see that every handling is performed with care.

Whether the fruit is to be sold at private sale, or at public auction, must be determined by the shippers. In part it may be necessary to follow the precedent of each market, but in any case, the consignment and commission system should be avoided. In some markets, fruit is sold through brokers at private sale. In others, there is a public auction at which all buyers may bid.

First class fruit usually brings a better price through private sale, provided the agent is a good salesman. In Chicago, where the experimental shipment of the past summer was marketed, Florida pineapples are sold at private sale.

MARKETS.

THE MARKETS THAT MAY BE REACHED. In Bulletin No. 14, it was stated that in the future development of the tropical fruit trade, the Eastern cities of the United States would probably be supplied by Porto Rico, Florida and Cuba, while the western coast could be supplied from Hawaii. Although it would not be wise to draw too general conclusions from a single experiment, it must be said that the results of the shipping investigations of the past summer point towards a much larger outlook for Hawaiian fruit marketing. The pineapples and avocados which were taken to Chicago in August, 1907 arrived in such condition as to justify the belief that these two fruits could be distributed over a much wider area than had been previously hoped. A leading dealer in fruits in Chicago representing a firm which ships fruit to Europe, as well as to all parts of America, on examining the pineapples, stated that, from a business point of view, if the carload were the property of his company it should be trans-shipped at once to New York; and further, that fruit in such condition could be shipped to any of the world's great markets. If future experiments of this kind shall confirm the results of the past season, it will be conservative to say that Hawaiian pineapples may be shipped to any part of the United States or Canada. It is possible that some kinds of fruits may not stand the distant shipment, and for these, markets must be developed nearer home. For example, the papaia will probably not endure a long journey by rail after reaching the mainland. The avocado travels much better, and with proper refrigeration and handling, can probably be carried far inland. This is true also of the mango. The carrying qualities of some other fresh fruits which have not been marketed on the mainland, have yet to be determined, THE CAPACITY OF THE MARKETS for tropical fruits, when once developed, can be judged by the enormous consumption of other fruits, which, a few years ago, were comparatively unknown, or were not shipped in quantity to eastern markets. To illustrate this, it may be said that more than twenty carloads of California grapes are sometimes sold in a single morning in the Chicago market. It is estimated by those most familiar with the fruit trade of Chicago that this market receives at present about twenty-five hundred carloads of pineapples per year. The present consumption of this fruit is only the faintest indication of the amount which will be consumed in the future provided proper methods for developing markets are pursued. This presupposes a marketing organization. Through such an agency a constant supply of fruit can be kept upon the markets during the season. By this means also, the over-stocking of one market while another is bare will be avoided, and by care in repacking on the part of the trans-shipping agent, fruit of uniformly first class quality can be supplied. This constant stream of good fruit flowing into the markets will rapidly increase their capacity. In Ogden, Salt Lake City and Denver it was found that there were dealers ready to receive Hawaiian pineapples in carload lots. With the exception of Reno, Nevada, these were the only markets visited between San Francisco and Chicago. No doubt all the large cities would take the fruit in freight lots.

Developing the fresh pineapple market means an enormous increase in the use of canned pines. The canned product on the shelves of the grocery store attracts little attention, a pineapple tin appearing the same as that containing any other fruit. On the other hand the fresh fruit is conspicuous by its unusual form and beauty, and if of good size, attracts the attention of every passerby. If reasonable in price, he buys and perhaps learns for the first time the taste of the pineapple; or if he has eaten the pineapple before, he learns for the first time the quality of the Hawaiian product. Later when the fruit is out of season he buys it in the can. If Hawaiian growers fear an over-production of pineapples, the best possible policy would be to keep selling the fresh fruit in as large quantities as the markets will consume.

The term "overproduction" merely expresses a relation in which the immediate supply exceeds the demand. Equilibrium may be restored not through any permanent reduction in the supply, but through increase in demand. This may be accomplished through more general distribution. As an illustration of this, there are more prunes and raisins sold today at remunerative prices than were grown at any time during the period of so-called over-production in California and Oregon. The rational move for the growers of pineapples is to organize their efforts to keep the demand constantly in advance of the supply.

In the discussion of markets the pineapple is spoken of in particular since that fruit is grown most extensively in Hawaii. There are those who are making a specialty of handling rare fruits and particularly tropical fruits in the great markets but this is comparatively a new business.

COMPETITION. It is not to be expected that Hawaii can have the whole field without competition, nor is it necessary. Some have thought that Hawaiian pineapples could not compete in price with the Florida product. The prices of the latter, as quoted in the Eastern markets, are somewhat misleading to the Hawaiian grower. Prices are usually quoted per crate. The Florida crate being much smaller than the Hawaiian, and the fruit also being of much smaller size, the comparison of prices means very little, except when brought to a per pound basis.

The quotations in Chicago on May 22, 1907 were about as follows:

42 size	$2.75 per crate
36 size	3.25 per crate
30 size	3.50 per crate
24 size	3.50 per crate
18 size	3.50 per crate

The "42 size" indicates that there are 42 pines per crate. The gross weight of a crate is about 75 pounds, and the net weight approximately, 60 pounds. It varies little with the size of the fruit. Therefore, about 60 pounds of fruit were selling on that day at $2.75 to $3.50 according to size of fruit. The finest of these, the eighteens, would average only 3.3 pounds per fruit, or smaller than any fruit which is shipped from Hawaii. The price of the best grade would be about the equivalent of $116 per ton. If this price were received for Hawaiian pines, there would be left a very considerable margin after deducting the costs of transportation. Hawaiian pines sold in September in Chicago for $155 per ton.

Although the Florida crop matures about the same time as that of Hawaii, when the Hawaiian pines were sold in Chicago in September, the market was bare of other pineapples and was reported to have been so for a long time. The dealers stated that very few pines were received during the summer and the Hawaiian product would find a ready sale.

The Florida output consists of about half a million crates per year. This, however, is subject to the uncertainties of weather to a greater degree than the Hawaiian crop. For example, the Florida crop for 1907, especially on the lower east coast, suffered seriously from a freeze and the entire pineapple area was visited by a severe drought. It is estimated that these two factors reduced the crop to about 40 to 60 per cent of the normal. Although the Hawaiian pineapple fields may at some future time suffer from severe drought, frost is unknown. The assurance of protection against this dread enemy which those in an "almost" frostless country are constantly in fear of should quite offset the difference in the cost of transportation.

Comparing the quality of the fruit, it has been recognized in all the markets visited during the past summer's investigations, that the quality of the Hawaiian pines as to flavor, texture and juiciness is far superior to the average. This may perhaps be attributed in part to soil and climate, but is probably due in a large degree to the variety which is grown in Hawaii most extensively. The "Smooth Cayenne" is recognized as a pineapple of fine quality, but Hawaii must not be blind to the fact that her competitors have chosen the "Red Spanish" because of its better shipping qualities. About 90 per cent of the Florida crop is said to be of this variety. If, however, the Smooth Cayenne can be successfully shipped with only a small loss in transit, it will outsell the Red Spanish.

It has also been supposed by some that Hawaii has a peculiar obstacle to contend with in the black rot of the pineapple. This, however, is incorrect since the same disease has been reported in pineapples which have been received in the Chicago markets from southeastern points. This disease is more prevalent in the Smooth Cayenne variety than in the Red Spanish.

PINEAPPLES.

SPECIAL CONDITIONS AFFECTING SUCCESS IN SHIPPING.

CARE IN HANDLING. The pineapple, as grown in Hawaii, is an unusually delicate fruit to ship. Its weight is the first factor in the problem. If an apple, a peach or an orange falls an eighth or a quarter of an inch, there is comparatively little momentum overcome when it strikes on a single point. When, however, a five to nine pound pineapple falls the same distance and comes to rest on a comparatively small portion of its surface, or when in sliding down a chute within a crate, it suddenly comes to rest against an adjoining fruit, the momentum causes bruising, or a destruction of the delicate cells within the fruit. In the case of a cured orange, or pomelo and in many other commercial fruits, there is a certain elasticity which tends to overcome bruising, and to protect the cell structure within. This is lacking in the pineapple. Further, the composite character of the pineapple is against it as a shipping fruit. It is really made up of many small fruits, or segments, placed closely together but easily separable from each other. A bruise which would not be sufficient to rupture the epidermis of most commercial fruits, would be sufficient to cause a separation between two of these segments, thus affording an opening for the exudation of juice. This provides the best possible medium for the growth of fungi.

The abundance of the juice in itself is another contributing factor.

It, therefore, becomes extremely important that the pineapple should be handled with utmost care. A large portion of the losses, which were observable in the fruits used in the experiments were plainly due to bruising. This care must be exercised at every step from the gathering in the field to delivery in the market. The grower, the shipper, the transfer companies, the steamship companies, and the fruit dealers each have their part to perform, and neglect or carelessness at any point in transit will result in loss to the owners of the fruit. It should never be thrown or allowed to fall even the slightest distance, nor be carried from the field to the packing house in bulk. The packing of a ton or more of pineapples loose on a wagon must result in the bruising of a good many fruits. In fact, it would probably pay to allow each pineapple to sustain no other weight than its own from field to packing house, where it has no protective material surrounding it. This could be accomplished by single layer crates. Only spring wagons should be used.

Under present methods of shipping, the packer should use liberal amounts of packing materials. In the experiments of 1906 it was found that the crates shipped with very little packing other than a paper wrapping, went through with very small loss. In the 1906 shipment, however, the fruit was more carefully supervised at every handling than was possible with the shipments of the season of 1907, or would be possible with commercial shipments except through a marketing organization. If all the fruit were handled by its owners, the use of very little packing material might be recommended. The transfer companies carrying the fruit from railroad to wharf should be cautioned in regard to the handling of delicate fruits. It is much easier to drop a crate, allowing it to fall an inch or two, than it is to place it where it belongs. Men who are accustomed to handling packages constantly, naturally acquire the easiest method.

The duty of the steamship companies, in relation to careful handling, is the same in part as that of the transfer companies.

The methods of loading and discharging the cargo, can be much improved upon. Pineapples are frequently taken on board by means of a sling which bruises the fruits where the rope binds the crate. In discharging the fruit even greater damage occurs when the chute is used. The crates are placed at the top of an inclined plane and are allowed to descend, by their own weight. In practice, nearly every crate comes to a sudden stop on the level plane at the foot of the chute with consequent bruising to the fruits within. It is difficult. if not impossible, for a man at the foot of the chute to control the matter so that the crates will come to rest slowly without jar. Some device must be sought which will obviate this bruising both in taking on and discharging the cargo. Where the fruit is hoisted by tackle attached to the boom, or freight crane, it would be possible to avoid the bruising by the rope if a frame were made in which the crates could be placed, so that the binding would be against the frame instead of the crates. This injury can be largely avoided by the use of strips of wood at the four corners of the sling to distribute the pressure. A more rapid method of loading and discharging, if there were sufficient business to justify it, would be an adaptation of the endless chain carrier with attendants at the top and bottom. By this means, the fruit could be handled much more rapidly and with less injury. Perhaps the present shipments of fresh pineapples would not justify any steamship company in putting in this apparatus for pineapples alone. If, however, there were a fresh fruit marketing organization, and a larger quantity shipped, this would appear to be the most satisfactory method of handling the crates at the ship. It may be said also that this method would be equally advantageous in the case of bananas wherever they are not trucked into the ship.

The responsibility of the commission merchant for the handling of fruit begins at the dock. The most satisfactory method of securing uniform care from this point to the retail dealer is in having the ownership pass from the grower to the wholesale dealer. It is useless to expect the average commission merchant to take the same care with consigned fruit that would be taken with fruit which he owns. As an illustration of this, it may be said the writer has seen Hawaiian bananas thrown fully ten feet and allowed to drop on the bottom of a wagon and then piled ten or twelve feet high, the loader standing on the lower tiers while the upper ones were being placed. No man would treat his own bananas in this way, nor is it intended to intimate that every commission house so treats fruit consigned to it. But how is the consignor to know what injury is the result of careless handling on the part of the consignee? It is even more important that the pineapples be handled with care at their destination than in the field, since they are riper. The chute is in use in many commission houses also as a means of transferring the fruit from the wagon to the basement of the fruit house. Although the distance is not so great as from the steamer's side to the wharf, the momentum acquired before the floor of the basement is reached, is sufficient to cause much bruising unless the operator at the foot of the chute is on the alert to prevent sudden jar. It is important also that the pineapples which have traveled 2,000 miles by steamer, should be picked over as soon as possible eliminating those which are decaying, and thus avoiding the spread of disease.

PACKING MATERIALS. Further tests were made of the relative value of hay and excelsior for packing pineapples in the crates. So far as the preservation of the fruit is concerned there appears to be no difference but the excelsior makes a better appearance. Corrugated strawboard was also tested as a wrapping about each pineapple but with no added benefit.

PINEAPPLE ROT, *Thielaviopsis ethaceticus.* The presence of this disease in pineapples was mentioned in Bulletin No. 14. As stated above, this disease is not peculiar to Hawaii. It, nevertheless, appears to be an important factor in the problem of fresh fruit shipments, and its control is a matter of great importance. Every means possible should be taken to avoid infection with the spores of *Thielaviopsis*. Even should it prove practicable to arrest the development of the fungus in pineapples before shipment, the importance of avoiding infection remains the same. In most fungus attacks upon ripening fruit, a large part of the injury results from increasing the number of vulnerable points. In the case of citrus fruits for example, it has been found [1] that much of the heavy loss sustained has been due to abrasions of the rind caused by brushing, or by the orange clippers, or from other sources. Although the exact life-history of *Thielaviopsis* in pineapples has not been thoroughly worked out, it is reasonable to suspect by analogy, some of the probable means of infection. First, infection may readily take place through the moistened surface of the stem where it is cut. Considerable benefits appear to have been gained by thoroughly drying the stem before packing so that it will be a less inviting field for spores. The Experiment Station has not yet been able to make a careful and exhaustive study of this subject. So far as observations have been carried, there is an advantage in allowing the fruit to stand on its crown for some time after gathering.

Second, innumerable vulnerable points are made by the bruising which takes place in shipping. Bruising of the fruit can be avoided by careful packing and handling. Third, it is probable that insects play their part in the spreading of this disease. Whether the pineapple mealy-bug, or the pineapple scale spreads this disease has not been proved, but the general nature of their attack makes it probable that they do. Mealy-bugs cluster at the base of the pineapple. They not only puncture the fruit but also cause it to crack open. The mealy-bug saps the vitality of the plant and mars the appearance of the fruit. The shipment of insect-infested fruits will also give Hawaiian pineapples a bad name in ports where careful quarantine regulations are enforced. Every effort should therefore be made to control insect pests in the pineapple fields. New fields should not be planted without carefully fumigating or dipping the plants to destroy the insects present.

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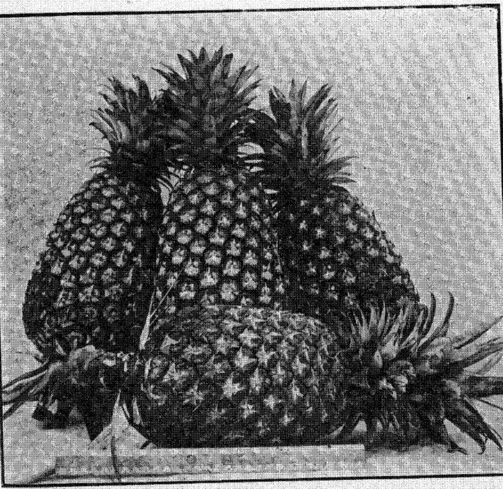
[1] Powell et al, U. S. Dept. of Agriculture, Bureau of Plant Industry, Bulletin No. 123.

FRUIT FROM DIFFERENT FIELDS.

There appears to be a very wide difference in the keeping quality of pineapples from different fields. During the trials of two years the average loss on fruits from some fields has run as low as 4.93 per cent, while from other fields it has averaged 25.77 per cent. While the evidence in hand is not conclusive it strongly suggests the importance of soil studies and fertilizer experiments in relation to the keeping quality of pineapples.



HAWAIIAN PINEAPPLES WITH STEMS CUT LONG.

LENGTH OF STEMS.

A large number of fruits were cut with stems two to three inches long and also others with stems one inch long or less.

The results are confirmatory of those of the year 1906, referred to in Bulletin No. 14. On fruits that showed a great tendency to decay in transit the part saved by cutting long stems averaged 17 per cent of the whole. The greater the tendency to decay, the greater became the saving on long-stemmed fruit. This 340 lbs. per ton or 17 per cent. would be worth $17 on a basis of 5 cents per pound.

BROKEN STEMS. There is a point in the pineapple stalk where the fruit can be broken from the plant. This point, however, is too close to the fruit, even closer than it has been customary to cut. The difference in favor of long stems as compared with broken stems was over 46 per cent.

PAPER WRAPPING. In the experiments of 1906 it was shown that the use of a paper wrapping about each fruit resulted in a marked reduction in the loss. These results also are confirmed by the trials made in 1907. Where the loss was heavy without wrapping there was a saving on wrapped fruit ranging from 4¼ per cent to over 9¼ per cent. On an average this difference in favor of wrapping was about 6.6 per cent.

It is interesting to note that fruits that were cut with long stems and also wrapped in paper and otherwise comparable with the above showed an average saving of 22.37 per cent of the whole as compared with fruits cut with short stems and packed without paper. This approximates the figure obtained by adding the gains resulting from these two devices when practiced separately. This experiment confirms the results obtained in 1906.

RELATIVE ADVANTAGE OF DIFFERENT PARTS OF SHIP.

During the experiments of 1907 tests were made of the relative advantages of the orlop deck and the after-deck for the carrying of pineapples. The 'tween-decks were not used at all since the results here the previous season were so decidedly unfavorable, and since this portion of the ship without a forced draft is manifestly without sufficient ventilation for carrying fruit. The temperatures are too high and the circulation of air is insufficient.

Pineapples from the three fields mentioned, were placed on the after-deck of the ship and were covered with a tarpaulin to protect them from the weather. The fruit on the orlop deck was ventilated, as usual, by means of a windsail. The results show no constant advantage in favor of either of these decks. While in fair weather fruit can be carried on the after-deck with a fair degree of safety, in stormy or cold weather this cannot be done. The tarpaulin over the crates on the after-deck, should be placed a sufficient distance above the crates to permit a free circulation of air beneath. Otherwise the temperatures will become too high [1]

Carrying fruit where it is exposed to the vicissitudes of weather can be regarded only as a makeshift. Any steamship company which aims to get the fresh fruit trade must equip its ships to handle fruit in all weather.

REFRIGERATION VERSUS VENTILATION.

Some pineapples were shipped by the trade in refrigeration during the early part of the season of 1907. The temperature was to be held at about 50 degrees.

An experiment was made to determine the value of such refrigeration. In the case of pineapples from fields A and B, no advantage resulted, the loss being practically the same in refrigeration as on the after deck. No fruits from field C were shipped in refrigeration. The temperature of the refrigerated compartments was held at about 50 degrees F. after it had been reduced to this point. The compartments were very full, and it is probable that the temperature of the fruit remained for a long time above that of the air of the room. The temperature of 50 degrees F. was not attained in one of the largest compartments until about eight P. M. of July 26, 2½ days from the time of sailing. This temperature, 50 degrees, is higher than is used for the refrigeration of other fruits. While it would not be fair to conclude that refrigeration is unsuited to pineapple shipments, it can be safely averred that an air temperature of 50 degrees attained two days or more after sailing, the fruit having been gathered several days preceding sailing, is of no particular advantage. A more effective refrigeration, which would bring the temperature of the compartment to perhaps 40 degrees within a short time after sailing, might give far different results. The cost of shipping by refrigeration is considerably greater than by ordinary freight. The lowest rates offered, so far as the writer is aware, for refrigerated freight from Honolulu to San Francisco is one cent per pound, about three times the cost for carrying on deck. If the simpler and cheaper method of transportation in ventilation should prove inefficient, it will then be necessary to conduct further experiments in refrigeration in transit using lower temperatures.

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[1] See "Transportation by Sea," page 7.

BANANAS.

One of the experiments was the shipment of Chinese bananas to San Francisco unwrapped. This variety is always wrapped when exported from Hawaii. The wrapping consists of dried banana leaves or occasionally, dried grass; the latter however is not a suitable material.

A serious disadvantage, is that this wrapping gives to the bunch of bananas the appearance of greater protection than it really has. The fruit, therefore, receives very much rougher handling. The experiment was made for these reasons and because some have thought that the wrapping might be a direct cause of heating. Fifty bunches were shipped in connection with the first experiments of 1907. It was intended that these fruits should receive the same care on board ship as the rest of the cargo of wrapped fruit. Through an error the bunches were suspended from hooks and hung clear of each other. They thus received better care than the wrapped fruit. Notwithstanding this, these fifty bunches arrived in San Francisco in no better condition than those which were wrapped; and it was evident from their bruised condition that had they been placed with the others and been loaded and discharged in the same manner, they would not have arrived in salable condition. The Chinese, or Cavendish variety, has a rind much more delicate than the so-called "Eastern" banana imported from Central America and the West Indies.

Since the bananas received unusually good care from the steamship company, the bruises were probably received from those who handled the fruit in Honolulu or in San Francisco. Both the consignor and the consignee should be slow to lay all the blame for losses at the door of the steamship company until they have made sure that none of it can be accounted for by their own methods of handling the fruit.

The so-called Eastern variety was introduced into Hawaii in 1904 under the name of "Bluefields" banana, Bluefields being an important port of shipment in the banana trade. It is well known that this variety is always shipped without wrapping both in steamships and by rail.

A great many offsets have been distributed throughout Hawaii from the stock introduced and propagated by this Station. Some of these fruits are beginning to appear, and a few bunches were shipped to San Francisco in November, 1907. One of these was overripe on arrival due to having been too near ripe when shipped. The others are reported to have arrived in most excellent condition and to have ripened with a bright color. This limited trial would not be a sufficient one upon which to base conclusions in the matter of shipping this variety without wrapping on the steamships from Honolulu, because these vessels are not specially equipped for the banana trade, as are those in the West Indian trade. It will not be long before a sufficient quantity of this fruit should be available to make a more extensive test.

If the Chinese, or Cavendish banana, continues in the Hawaiian trade, some methods of protection, preferable to those now in use, should be sought. On the mainland a cylindrical package known as a "banana drum," is coming into use in shipping bananas by express from the great central markets to the tributary territory. These are of heavy pasteboard or strawboard with three hoops and have a thin, wooden bottom. At the top, a lining of heavy wrapping paper extends about a foot above the top of the drum. The bunch of bananas is packed within this drum and the paper tied about the stem, which thus makes a convenient handle for lifting the package. A similar drum is also being made with veneer sides in place of the pasteboard. These are quoted in Chicago at nine cents for a twelve inch drum, or ten cents for a fourteen inch drum; "knocked down" and crated for shipment. The paper drums cost about half this amount. It would be well to make a trial of these packages, as in case they should prove desirable, they could undoubtedly be manufactured here in Hawaii. Such packages would probably not receive as rough handling as the bunches wrapped in banana leaves.

AVOCADOS.

The results set forth in Bulletin No. 14 regarding methods of picking, packing and shipment of avocados have been confirmed by the trials of 1907. Through an accident, many of the packages did not receive the treatment which had been planned, resulting in rather high percentages of loss. All that were packed and treated as described in Bulletin No. 14 gave satisfactory results.

The refrigeration given the avocados was the same as referred to above in the case of pineapples except that the temperature of 50 degrees F. was attained much more rapidly in the room where the avocados were placed. Although the fruit which was picked, packed and placed on board the steamer, as directed in Bulletin No. 14, arrived in San Francisco in good condition, it would have been better, judged by market standards, had it been firmer. The observations of this and other experiments, suggest that a temperature lower than 50 degrees is necessary for the most successful shipment of avocados. It is recommended, tentatively, that the temperature be held as low as 40 degrees.

Observing a few essential points in packing and shipping, the avocado appears not to be a difficult fruit to export. It is necessary to use care in picking and packing so as to avoid bruising. It seems hardly necessary to say that avocados which have been shaken from the tree, or knocked off with sticks or stones, or allowed to fall, even after being cut, are unfit for shipment. Yet such fruit has repeatedly been shipped and has been in part responsible for the impression that avocados are an uncertain shipping fruit. To insure success the fruit, after careful picking, should be wrapped in paper and packed in single layer crates. *The spaces between the fruits should not be filled with paper,* as is often done. This paper makes refrigeration much more difficult, retaining the natural heat of the fruit until ripening has begun. Perhaps the most striking essential in shipping avocados is to get the fruit into refrigeration promptly after packing. It is characteristic of the avocado that it begins to soften very soon after picking. After this softening has begun, it is too late to arrest the ripening process and place the fruit on the market in a firm condition as required by the dealers. This fruit should arrive in the market perfectly hard. Fruit that is beginning to soften, even though it may be in prime condition for immediate use, will not sell readily. The dealers fear the risk of loss in case the fruit is not placed with consumers immediately.

The market for avocados is limited at present by reason of the high price, and in most inland cities this fruit is little known. Experience has gone far enough, however, to demonstrate that once the avocado becomes known and of moderate price, there will be markets for large quantities. First-class avocados in good condition sell in San Francisco for about $2.50 per dozen, and there is little difficulty in disposing of all that arrive at the present time, provided only that they are firm and of good quality.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 22.

Pineapple Shipping Experiments in 1908.

BY J. E. HIGGINS,

Horticulturist, Hawaii Experiment Station, United States Department of Agriculture.

The pineapple industry continues to develop. It has attained larger dimensions than would have been thought of a few years ago. The output has increased so rapidly that some growers have even expressed the fear that production might for a time exceed consumption. With the conviction that the best preventive for overproduction lies in the direction of increased distribution; with the belief that the fresh pineapple is one of the best possible advertisements for itself and for the canned product; and with the further fact in mind that whatever can be done to perfect methods of shipping will increase the output of fresh pineapples, this Station has continued its investigations in pineapple shipping during the past season. A number of new problems have been taken up and some of the experiments of previous years have been repeated with confirmatory results.

The experiments were on a co-operative basis, being entered into by the Wahiawa Consolidated Pineapple Company, the Hawaiian Pineapple Company, the Thomas Pineapple Company, the Matson Navigation Company, and the Hawaii Experiment Station. The shipment was made on the Steamship "Hilonian," sailing from Honolulu August 11, 1908. The plan of the experiment was similar to that outlined in Bulletin No. 14 and Press Bulletin No. 21.

RESULTS OF TRIALS.

The value of "curing" the fruit was one of the important problems which had not been taken up in a systematic way until this season. The term "curing" as here applied refers to the holding of the fruit for a day or two before packing. During this time most of the stems will shrivel and the cut surfaces will become dry and resistant to infection. By this means also, the excessive heat of the fruit is eliminated. During the warmer part of the day the temperature of the fruit in the field is much higher than the temperature of the air in the shade. In some observations between 7 A. M. and 8 A. M. it was found that the temperature at the center of the fruit was only 70° Fah., while the air temperature in the shadow of the same fruit was 78° Fah. Inserting the thermometer one inch, the reading was 76° Fah. Before 10 A. M. the temperature of the fruit in the center was 82° Fah., and in the warmest part, 95° Fah. The fruit continued absorbing heat. At 2 P. M. the reading was 105° Fah. in the warmest part.

It will thus be seen that the pineapples, as ordinarily gathered, have absorbed a large amount of heat. If packed before this has been eliminated, the ripening and decay of the fruit will be greatly hastened.

To test the practical value of holding the fruit before packing, a part of the shipment was gathered two days, and another part one day before packing; while still a third portion was gathered and packed the same day. The results indicated no advantage in holding the fruit longer than twenty-four hours, this being sufficient to permit of the drying of the stems and the cooling of the fruit. Possibly, a longer time would be required during the damper weather when the winter crop is being harvested.

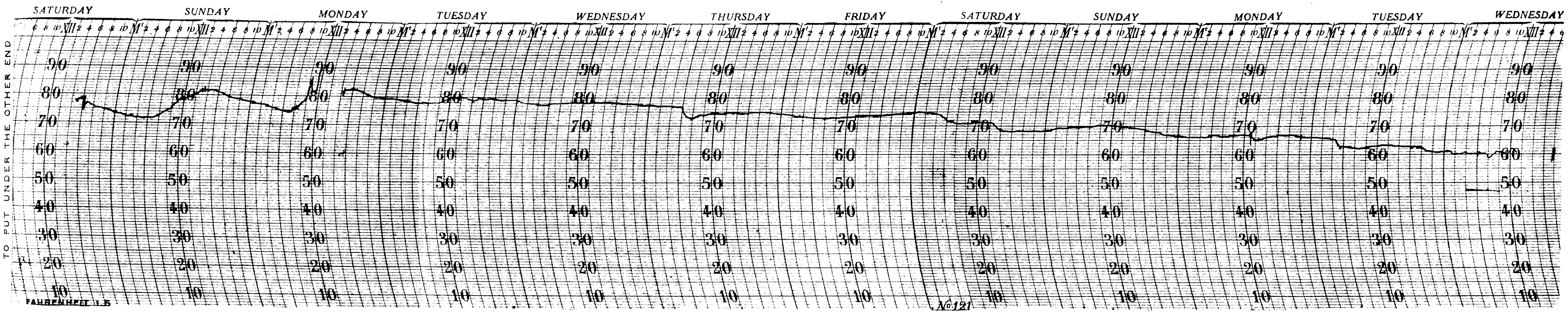

PLATE I. THERMOGRAPH RECORD.

The above shows a record of the temperature of the air surrounding pineapples in transit from Saturday, August 8th, to Wednesday, August 19, 1908. The interruption of the record on Monday, August 10th, was coincident with the transfer of the fruit from car to steamship.

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Temperature in transit. It is interesting to note the temperature of the air surrounding the fruit in transit, but it must be remembered that this is not a true record of the temperature of the fruit, since the latter must acquire the air temperature slowly. If packed when cool, it will probably not acquire the greatest heat indicated during the short time in the car in Honolulu or in transit. On the other hand, it will not be quite so cool as the air temperature by the record sheet on arrival in San Francisco. The record exhibited by the accompanying illustration (Plate I) was made by a thermograph placed in the car, and later in the 'tween decks of the ship. In both cases it was located among the crates with a view to giving a fair average temperature. From Saturday at 5 P. M. until Monday between 10 A. M. and 12 noon, the fruit was in the car, the doors being open until about 7 A. M. on Monday, when the train departed from Wahiawa. The thermograph was installed in the ship at about 4:30 P. M. of the same day. Several sudden drops in temperature may be noted during the time spent at sea. These were coincident with the opening of the hatches and the hoisting of the windsail after rough weather.

The poop deck. The record of temperatures on the poop deck was taken by means of a self-registering thermometer which was read twice each day. This thermometer was suspended in a narrow shaft between the crates, arranged for the purpose at the center of the deck. The thermometer was suspended soon after getting to sea on August 11th and the maximum reading for the remainder of the day was 79° Fah. On the 12th, the maximum was 74° at the noon reading, and 71° at the 5:30 P. M. reading. From this time to the end of the voyage, the temperature constantly fell, always remaining below that in the 'tween decks.

Comparing the results in the fruit carried in these two parts of the ship, neither showed any advantage over the other. Had there been continuous rough weather, so that the hatches could not have been opened, the results might have been different. The electric ventilator installed to ventilate the 'tween decks of the S. S. "Hilonian," marks an important step in progress in Hawaiian fruit shipping. The one machine, however, is inadequate for the space and should be supplemented by another. There can be no question that the 'tween decks adequately ventilated will afford the safest and best part of the ship for pineapples. Indeed nothing short of this will meet the situation.

Care in handling. The conditions under which the experiments of the past season were conducted, afforded an opportunity for careful handling from the field to the wharf in San Francisco. The greater portion of the pineapples were brought from the field to the packing house in lug boxes containing only a reasonable number of fruits each, spring wagons being used for this transportation. At Honolulu the car was placed on a siding close to the ship and thus carting, involving two handlings, was avoided. It is due the Matson Navigation Company to state here that its handling of the fruit evinced much care. In loading, the sling was provided with adjustable protectors to prevent the binding of the ropes against the slats of the crates. In discharging, a man was stationed at the side of the chute and about half way between the deck and the wharf to stop the crates. By this means the men at the end of the chute were able to prevent a sudden jar when the crates reached the wharf. The loss by bruising which oftentimes is very heavy, was reduced to almost insignificant proportions by this careful handling from field to market and by good packing.

Fruit from different fields. The results of comparisons of the shipping qualities of pines from different fields in earlier experiments were confirmed by the trials of the past season. These results were fully set forth in Bulletin No. 14 and in Press Bulletin No. 21, and need not be repeated here.

MARKET PROBLEMS.

Size of Fruits. There has recently grown up a tendency with some growers to ship very small pineapples. The reasons for this are that the small fruit carries better with less bruising and less decay. Although the price per dozen is low, these fruits sometimes sell quite readily. It is not recommended that any great quantity of the largest pineapples, weighing between six and nine pounds per fruit, should be shipped since the demand for these is small. They appeal to a fancy market, and, so far as such outlet for them can be developed, they should be shipped; but the demand is for the medium sized fruit. There is a danger in the practice of shipping the very small fruits, including those weighing three pounds and less. The fact that a good many of these have come into the San Francisco market from Honolulu has led some to suppose that the Hawaiian pineapple soils were becoming exhausted, and that these small fruits represented a decline in the quality of the product. As indicated above, this is not the cause, which rather is of a purely commercial nature. The Hawaiian pineapple growers, however, should be aware of the interpretation which is being made and guard the reputation of their product by shipping first class fruit of medium size, and such quantity of larger sizes as prove profitable. The fruit which sells most readily, and at the same time is superior in size to most of the fruit with which it competes, weighs from four to five pounds.

Insect Quarantine. Developments have arisen during the season which have necessitated some changes in the practices of the growers and shippers in relation to insect control. The California State Board of Horticulture have ruled that pineapples entering the State must be fumigated before arrival, or, in other words, that on arrival they must be free from living insects. The law of California relating to the inspection and quarantine, is plain and Mr. Ehrhorn, Quarantine Officer of the port of San Francisco, is simply carrying out his responsibility in detaining infested shipments of pineapples. The shipping of clean fruit is of mutual interest to California, to protect the orchards of that state, and to the pineapple growers of Hawaii, to prevent the loss of shipments. In the solution of the problem, Mr. Ehrhorn has taken an active interest and we are indebted to him for valuable assistance and advice.

The remedy for this difficulty lies at home. Every effort should be made to grow clean pineapples. For the protection of the fruit and the reputation of the growers, it is greatly to be desired that even dead scales and mealy-bugs should not disfigure the fruit, but in spite of the most rigid methods of cultivation, it is probable that a few insects will be present in almost any shipment. It is, therefore, absolutely necessary that the fruit should be carefully fumigated, and that special vigilance be exercised to the end that no stray fruits that have not been treated should get into the crates. The writer has seen shipments in which a few pineapples were found in the crates harboring living insects, while the other insects in the crate were destroyed. This appears to be due to carelessness in preparing the shipment.

The entomologist of the Station gives the following recommendation for the fumigation of pineapples for shipment:

For every 100 cubic feet of air space the dosage is as follows:

1½ ounce (by weight) of potassium cyanide,
3 fluid ounces of sulphuric acid,
6 fluid ounces of water.

This dosage with an exposure of 60 minutes has been found effective in killing all forms of the mealy-bug, *Pseudococcus citri* and the scale, *Diaspis bromeliae,* when liberated in an air-tight chamber.

The fumigation under canvas has not been uniform in results. It has been necessary to extend the time when using canvas and the length of time has depended upon the facilities for doing the work. In using a canvas treated effectively to prevent leakage, over an air-tight floor, the time is approximately that for an air-tight chamber. Generally speaking, however, the time for fumigation under treated canvas should be extended to at least one hour and thirty minutes. The loss of time in the labor required for the fumigation work can be balanced by increasing the capacity of the fumigating outfit.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 23.

The Influence of Manganese on the Growth of Pineapples.

BY W. P. KELLEY,

Chemist, Hawaii Experiment Station, United States Department of Agriculture.

For a number of years the pineapple growers in the Wahiawa district have observed that on certain sections of their land pineapples do not grow well. On these areas the young plants begin to grow as on the best soils, but in the course of a few months the leaves begin to show a reddish-purple color, which soon gives place to a yellowish-white appearance, and this color persists throughout the remaining life of the plant. Many of these plants never bear fruit; that which is produced, however, is always of inferior size and quality. These areas are quite definite and with the rapid expansion of the pineapple fields in recent years, the land thus affecting this crop has been found to be much greater in extent than was formerly thought. All efforts of the best growers, including the application of fertilizers and lime, good tillage, drainage, etc., have failed effectually to change the growth of the pines on these lands.

A number of investigators have from time to time studied the effects of manganese on plant growth. Such studies, however, have involved merely the application of small amounts of manganese to soils. The smallest amount of manganese found in our best pineapple soils is five times greater than the heaviest artificial application made in previous experiments, while in our black soils the amount is 120 times greater. Previous experiments with manganese have been concerned with the possible stimulating effect of minute quantities. In our pineapple districts, manganese is an important element in the soil. The present bulletin is a preliminary report on the first investigation ever made of soils in which manganese is a dominant and determining factor of plant growth.—E. V. Wilcox.

In consideration of the extent of such soil, and its unusual character, the Hawaii Experiment Station has undertaken an extended investigation of the question. This work is still in progress, but it is thought that results of sufficient importance and scientific interest have been obtained to warrant their publication at this time. This bulletin should, therefore, be regarded as a preliminary report, rather than a complete discussion of the subject.

The pineapple growers have noticed for several years that the soil which produces yellow pines in most instances is dark in color, whereas that producing thrifty, green plants is usually red. From this difference in color, it is common in Hawaii to speak of pineapple soils as being red or black, meaning thereby good or poor pineapple soil; and it is in this sense that the terms red and black soils are used in this paper. In addition to this difference in color, the black soils appear to have a finer texture than the red soils. When reasonably dry and in good tilth, the red soil usually has a granular or "shotty" texture, while the black soil, under similar conditions, is reduced to a finer state of division. Upon thoroughly wetting, however, either of these types[1], may be crushed between the fingers to an almost impalpable mass; and indeed, to such a fine state of division that practically all of it will pass through a one hundred mesh sieve. There is, therefore, very little true grit in this section. It should be remembered in this connection that practically all soils of Hawaii are of volcanic origin, and it seems that in this district, a very complete disintegration of the lava has taken place, which, in some places, extends to a depth of thirty feet or more.

In certain other pineapple sections of Oahu, particularly near Pearl City and Pupukea, a similar condition exists, but since there is a larger area devoted to this crop, and a greater extent of black soil in the Wahiawa district than in other sections of the Islands, it was decided to undertake this investigation at Wahiawa. Accordingly, in September, 1908, two extensive series of fertilizer plot experiments were begun; one on red soil, and one on black. There was a twofold object in these experi-

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[1] The word "type" is not used in this bulletin in its usual sense, but rather for the sake of brevity.

ments,—first, to determine the fertilizer requirements of pineapples in Hawaii; second, to ascertain the cause of pineapple yellowing on the black soil. This bulletin deals with the latter of these only.

At the beginning of these experiments, a number of samples of soil and sub-soil were taken from various parts of the district. About one-half of these were from the black soil, where the pines were very yellow; and one-half from red soil, producing good pines. The samples of soil were taken to a depth of eight inches; and the sub-soil from eight inches to twenty inches below the surface. Each of these samples represents a composite, taken from not less than six different places; and, therefore, the average of the six samples of each type may be looked upon as representing not less than thirty-six different places in the red and black soils, respectively. In the following table is given the average water-free composition of the two types as determined by the methods of The Association of Official Agricultural Chemists.

TABLE I.

Average Composition of	Red Soils	Red Sub-Soil	Black Soils	Black Sub-Soil
Insoluble matter	42.82%	41.42%	35.26%	37.73
Potash (K_2O)................	.59	.63	.91	.87
Soda (Na_2O)................	.27	.25	.31	.41
Lime (CaO)	.36	.48	.97	.58
Magnesia (MgO)	.39	.38	.47	.41
Manganese oxide (Mn_3O_4)...	.37	.20	5.61	4.90
Ferric oxide (Fe_2O_3)	27.82	30.10	22.58	22.96
Alumina (Al_2O_3)	10.04	10.37	15.39	17.20
Phosphorus pentoxide (P_2O_5)	.08	.12	.27	.16
Sulphur trioxide (SO_3).......	.11	.08	.17	.06
Volatile matter	15.14	13.74	17.61	13.67
Titanium oxide (TiO_2).......	2.01	2.49	.88	1.08
Total	100.03	100.26	100.43	100.03
Nitrogen (N)	.32	.24	.37	.20
Acidity (1)	1235	......	98	......

1. Calculated to pounds of CaO per acre foot.

The growers at Wahiawa often refer to their black soils as being sour, and many of them are inclined to attribute the yellow, dwarfed appearance of the crop on this land to this cause. Investigations, in other countries have pointed out that the pineapple plant is very sensitive to acidity[1]. But in view of the fact that the determination of acidity in these soils shows the presence of much less actual acidity in the black soil than in the red soils, (see table above), it seems that, considering this factor only, the black soils should be the more productive of the two. In fact, every sample of the black soil analyzed contained less acidity than any of the red soils, and furthermore, some of the black soils tested were found to be neutral. It, therefore, seems reasonable that some cause other than acidity is bringing about the unfavorable growth. By reference to the previous table, the black soils are shown to contain even more of the so-called plant foods than the red soil, and in this connection, it is especially noteworthy to point out that the black soil is well supplied with nitrogen, phosphoric acid and potash.

It is well known, however, that the usual chemical analysis of a soil is not sufficient to determine its crop producing power; that the chemist often fails to recognize certain conditions in the soil, which have great influence on crops; and further, that the usual chemical anlysis fails to indicate the availability of the elements in the soil; but without discussing this subject further, it is sufficient at this time to say that the application of liberal amounts of various high grade fertilirers. in conjunction with good tillage, drainage, etc., has not resulted in overcoming the yellowing of pines on this land.

The plots of black soil, to which the Station applied nitrogen, phosphorus, potassium and calcium in various forms and amounts do not indicate an effectual remedy for the yellow-stunted growth of pines there. Some of the same applications to red soil, on the other hand, are proving highly satisfactory. What then is the cause of this phenomenon?

By again referring to the previous table, one striking difference in the composition of the two types is apparent, namely, in their manganese content. In order to bring out this point more forcibly, the following table is submitted, which shows the complete analysis of the soils containing the maximum, minimum and average percentages of manganese oxide found in each type.

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[1] Bul. 68, Florida Experiment Station, page 697.

TABLE II.

	BLACK SOILS			RED SOILS		
	Max.	Aver.	Min.	Max.	Aver.	Min.
Insoluble matter	33.45%	35.26%	34.86%	39.07%	42.85%	44.00
Potash (K_2O).............	.83	.91	1.06	.76	.59	.59
Soda (Na_2O).............	.40	.31	.29	.33	.27	.29
Lime (CaO)...............	1.39	.97	.36	.29	.36	.24
Magnesia (MgO)...........	.54	.47	.40	.35	.39	.41
Manganese oxide (Mn_3O_4)	**9.74**	**5.61**	**3.91**	**.91**	**.37**	**.15**
Ferric oxide (Fe_2O_3)......	19.65	22.58	26.39	24.98	27.82	27.94
Alumina (Al_2O_3).........	15.50	15.39	14.85	14.73	10.04	11.91
Phosphorus pentoxide (P_2O_5).........	.21	.27	.18	.10	.08	.03
Sulphur trioxide (SO_3)..	.16	.17	.13	.17	.11	.11
Volatile matter...........	17.73	17.61	16.33	17.84	15.14	13.94
Titanium oxide (TiO_2)...	.73	.88	1.54	.23	2.01	.28
Total.................	100.33	100.43	100.30	99.76	100.03	99.89
Nitrogen (N).............	.39	.37	.30	.34	.32	.29

Since the above analyses were made, numerous other samples have been drawn both from red and black soil; and in every instance, the samples drawn from sections where the pines are yellow, have been found to contain large amounts of manganese, whereas, those taken from the red soil, on which thrifty pines grow, contain little of this element. In general, the black soils contain from ten to fifty times as much maganese as the red soils[1].

All the samples previously referred to were drawn from extremes, that is, either from sections which produce very yellow plants, or from soils producing very thrifty, green pines. The yellow and green areas are not separated by sharp lines of division, however, but rather gradually merge the one into the other.

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[1] It has been previously pointed out that some Hawaiian soils contain large amounts of manganese (see Press Bulletin No. 18, this Station); but no effort has been made to correlate yellowing of pineapples with the occurrence of manganese in the soil.

There is, therefore, an intermediate area surrounding the yellow spots on which the pines show the yellowing effect to a lesser degree. With the view of determining whether the maganese likewise decreases in passing from the black soil to the red, several series of samples from different places, were drawn at regular distances apart, in passing from the black to the red soil. From the analysis of these samples, a very close correlation between the yellow color of the pineapples and the manganese content of the soil was found to exist.

The following table will show the percentages of the oxide of maganese in black, intermediate and red soils.

TABLE III.

	Black.	Intermediate.	Red.
Manganese oxide (Mn_3O_4)	5.61	1.36	.37

It seems, therefore, that some correlation exists between the yellowing of pineapples and the amount of manganese in the soil.

According to Leclerc[1], manganese is an almost universal constituent of soils, and it is often not determined in soil analysis for the reason that it is not usually regarded as a necessary element of plant food, and is thought to have little or no economic importance in crop production. Among all the analyses, to which the author has had access, none have been reported that contain more than a few tenths of one per cent of Mn_3O_4.

The solubility of a substance in the soil, however, determines in a large measure its influence on plant growth. Sodium, for instance, while not usually considered as an essential to plant growth, when present in the form of a soluble salt, is known to exert a marked influence on crops. Wheeler and Hartwell[2], at the Rhode Island Experiment Station, have shown that soluble sodium compounds may even partially take the place of potassium in the development of certain plants and in certain instances sodium may perform a physiological function in the development of these plants. The occurrence of large amounts of soluble sodium compounds in the soil, however, is known to be very detrimental to the growth of the plant. As is well known, sodium and potassium are closely related elements and have many properties in common. Maganese and iron are likewise closely related. It has been shown that when certain plants are grown in culture solutions containing very small amounts of iron, the application of a small amount of soluble manganese brings about new vigor and increased chlorophyl production and in this connection the solubility of the maganese and iron in the black soil becomes a matter of interest. The chief function of iron in plants seems to be connected with the production of chlorophyl, and since the general appearance of the yellow pines indicates that the cholorphyl has been affected the possibility of some influence on the part of the manganese at once suggests itself. In this connection, Loew and Sawa in commenting on the work of Birner and Lucanus say: "In regard to the behavior of plants toward manganese compounds but few experiments have been made and these show that manganese cannot replace the related iron in regard to the production of chlorophyl; and that the manganous and manganic phosphate suspended in culture solution can exert an injurious effect."[1]

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[1] Cited by Schreiber in Revue Generale Agronomique, January, 1906.

[2] Nineteenth Ann. Rept. Of R. I. Experiment Station.

With the view of determining the solubility of the manganese and iron, a number of samples of both red and black soils were extracted with a one-per cent solution of citric acid. In this determination, 200 grams of air-dried soil, were treated with 2000 cc of one per cent citric acid for forty-eight hours, with occasional shaking. At the end of this time the solution was filtered, and the iron and manganese determined in the filtrate. The following table will show the results, expressed in percentages of air-dried soil:[2]

TABLE IV.

	Black Soil.	Red Soil.
Mn_3O_4	.733%	.028%
Fe_2O_3	.243	.379

Estimating that an acre foot of this soil weighs about 3,500,000 pounds, we find that the black soil contains, on an average, about 23,755 pounds of citrate soluble mangano-manganic oxide per acre foot, while the red soil is found to contain only 980 pounds in the same area. It would, therefore, be extremely surprising if this large amount of soluble manganese were without influence in the soil. It is sufficient here to point out the relations between the citrate soluble iron and manganese in the soil. From the table it is shown that these stand in inverse proportions.

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[1] Bul. of the College of Agric. Tokio Imp. Univ., Vol. 5, No. 2, p. 162.

[2] Average of the determination in six samples.

In the strong acid digestion of the black soils, it was noticed that considerable frothing or effervescence developed upon slightly heating the same, and subsequently, this was found to be due to the escape of chlorine gas. Numerous samples have been treated with hydrochloric acid, and in every instance, the black soils have been found to liberate large quantities of chlorine; the red soils do not possess this power.

In the determination of volatile combustible matter, it was also observed that after heating the black soil just below redness for some hours the sample still retained some of its dark color; but upon subsequent stronger heating, further loss in weight occurred and the soil took on a dark brown color. From these facts, it seems likely that at least a part of the manganese in the black soil exists in the form of higher oxides. The black color and the liberation of chlorine gas suggest the presence of manganese dioxide, or of sesquioxide of manganese.[1] It is, of course, likely that the dark color is caused in part, at least by organic matter.

It is reported that in some of these fields the first crop of pines, on virgin soil, showed but little yellow color during the first twelve months of their growth. Later, however, these plants became very yellow and almost ceased to grow. With the continued growth of pines on this soil, its color also seems to become darker. A number of the yellow plants were pulled up and it was found that the soil adhering to the larger roots was darker in color than the general soil. Aso reports that wheat grown in solutions containing a small amount of manganous sulphate was found to contain manganese dioxide adhering to the roots.[2] These facts, together with the observation that the cultivation of pines on this soil renders it less adapted to the crop, indicates that there is some change brought about in the soil by the crop itself; and since the soil of this entire section has arisen from the disintegration of lava, which, in its original state could not have contained either of the black oxides of manganese, it seems reasonable that in the growth of pines a change in the state of oxidation of the manganese takes place.

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[1] See "Soils" by Hilgard, p. 283.

[2] Bulletin of the College of Agriculture, Tokio Imperial University, Vol. V, No. 2, page 183.

In connection with the investigation of the soil, a study of the yellow plants has also been undertaken. It was formerly believed that the etiolated appearance of the pines was caused by some pathological or entomological infestation; but as yet all efforts to determine such infestation have proven fruitless. No insect or fungus, which is known to produce this phenomenon, has been found on these plants The root system of the yellow plants was found to be dwarfed and much less extensive than that of vigorous, green plants. In many instances, the roots are covered with a black coat, and have but little indication of life. The yellow plants possess but few root hairs. The healthy green pines on the contrary have a very extensive root system, sometimes reaching out to a distance of several feet from the plant.

Some analyses of the ash from both the green and yellow plants have been made, and while a sufficiently large number of plants have not been analyzed to warrant positive conclusions, it seems that the entire metabolism of the yellow plants has been disturbed. A number of young plants, about four months old, taken from both red and black soils, and also an equal number of plants two years old, were examined. A composite sample, made up of an equal number of leaves from the same portion of these plants, was analyzed. In the following table the percentages of manganese oxide in the ash of these plants is given:

TABLE V.

	Yellow Pines. (4 months old)	Yellow Pines. (2 years old)	Green Pines (4 months old)	Green Pines. (2 years old)
Mn_3O_4......	2.12%	1.15%	1.65%	1.68%

In consideration of the very large percentage of easily soluble manganese in this soil it is rather surprising that a higher percentage of this element is not found in the pineapples grown thereon, especially, since it is generally considered, that, in the presence of soluble substances, plants have the power of taking up these substances in considerable amounts. It is interesting here to note the smaller percentage of manganese in the ash of the yellow plants two years old, than is found in the younger pines. In the case of green plants, the ash is found to contain about the same percentage of manganese in each of the **two** stages. In this connection, other investigators have found that many other plants contain notable amounts of manganese. Schroder, for instance, found in the ash of the leaves of the Norway spruce 35.53% Mn_3O_4. [1]

The fact that the ash of other plants, such as wheat, barley, etc., grown under normal conditions, contains not only a higher percentage of nitrogen and potash, but also more of these substances in actual pounds, during the advanced growing period, than at maturity, has been pointed out by several investigators. In a very exhaustive investigation of this subject, Wilfarth and Romer[2] at the Ducal Experiment Station, have shown that the decrease of the actual total nitrogen and potash in wheat and barley, as they pass from the growing stage into maturity, can be explained in no other way than that these substances are actually returned to the soil. These inevstigators found that of the potash in wheat and barley at the time of flowering only 58.87% of that in the former, and 64.97% in the latter remained at maturity; and while it is true that potash is necessary to plant growth, and manganese is not usually so considered, the suggested analogy in the two cases is none the less interesting.

Manganese, when applied in small quantities, has been shown by several workers to produce the effect of stimulation. Nagaoka[3] at the Tokio Imperial University, effected an increase in the yield of rice to the extent of 37% by the application of 77 kilos of manganous sulphate per hectar. At the Woburn Experiment station, the stimulating power of manganese on wheat and other crops has also been determined; and other investigators have found that small amounts of various manganese compounds produce the same effect. The fact, however, that small quantities of a substance exert a stimulating effect does not necessarily imply that larger quantities would be beneficial. In the animal organism, for instance, a small amount of alcohol is known to produce the effect of stimulation, whereas larger amounts have a depressing effect. The same may be said of ether and chloroform. With plants, there are several well known examples of the same condition. Katayama [1] and others have shown that ferrous sulphate in small quantities produces a stimulation of certain plants; and whether or not this is brought about by bringing into solution some of the dormant bases of the soil, larger quantities of the same substance are often referred to as actually poisonous to the plants. [2] Sutherst[3] has shown that the application of small amounts of various manganese compounds, including the dioxide, has a stimulating effect on maize, but he points to the work of Salamone as indicating that larger amounts of these substances are detrimental.

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[1] Cited from the Bul., College of Agric., Tokio Imp. Uni., Vol. V, No. 2, p. 161.

[2] Researches of the Ducal Agric. Expt. Station, on The Assimilation of the Elements of Nutrition by Plants During Different Periods of Their Growth. Die landwirtschaftlichen, Versuchsstationen, Vol. 63, 1905.

[3] Bul., College of Agric., Tokio Imp. University, Vol. VII, No. 1.

The question of how these substances produce stimulation, in small quantities, and a depressing effect, when present in large quantities, is not thoroughly understood; but that such is the case, is generally accepted. Aso [4] for instance, has shown that a given amount of manganese may produce stimulation of rice, whereas the same amount of this element, when applied to wheat and barley, may, under certain conditions, result in decreased vigor and the development of a yellow color in the plant. This author has further pointed out that the depressing effect of such applications of manganese is usually more marked in cold weather than in warm; and with the return of warm weather, in some instances, these plants were able to entirely overcome the stunted growth and yellow color.

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1. Bul. College of Agric., Tokio Imperial University, Vol. VII, No. I.

2. "Agriculture" by Storer, Vol. I, p. 216.

3. "Manganese Compounds as Fertilizers for Maize," The Transvaal Agric. Journal. Vol. VI, No. 23.

4. Bul. College of Agric., Tokio Imperial University, Vol. V, No. 2, pp. 177-185.

We find a parallel condition at Wahiawa, where the pineapples on soils which contain an intermediate quantity of manganese, have been repeatedly observed to become decidedly yellow during the winter months; but such plants sometimes entirely overcome this condition with the return of warm weather. It should be mentioned in this connection that sugar-cane grows exceedingly well on these manganese soils, where the pineapples refuse to grow.

Bertrand [1] some years ago, found that the ash of oxidizing enzymes contains considerable amounts of manganese, and that the addition of soluble manganese salts to the oxidase greatly accelerated their oxygen carrying power. Woods [2] has shown that the yellow spots, which sometimes occur on leaves of certain plants, have a greater oxidizing power than the green parts of the same plant. In seeking an explanation of the yellow color produced by the application of manganese sulphate to barley, Loew and Sawa found that such plants are more vigorous oxidizing agents than those not treated with manganese. Summarizing these effects, they say: "Manganese exerts, in moderate quantity, an injurious action on plants, consisting in the bleaching out of the chlorophyl. The juices of such plants show more intense reactions for oxidase and peroxidase than the healthy control plants. Manganese exerts further a promoting effect on the development, still observable in high dilution, while the injurious effects disappear under this condition. It is probably that soils of great natural fertility contain manganese in an easily absorbable condition, and this forms one of the characteristies of such soils.'' [3]

With the view of ascertaining whether yellow pineapple plants are more vigorous oxidizing agents than the green plants, a small portion of both yellow and green leaves were macerated with crushed glass, allowed to stand about an hour, and the extract was tested for oxidase, using the guiacum and aloin tests; the following table will show the results:

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[1] Compt. rend. Vol. 124, Page 1032.

[2] Abstracted in E. S. R. Vol. XII, p. 216.

[3] Bulletin, College of Agriculture, Tokio Imperial University, Vol. V, No. 2, p. 172.

TABLE VI.

	Guiacum	Aloin.
Yellow leaves	Deep blue.	Rose red.
Green leaves	Pale blue.	Faint red.

It is thus shown that the plants grown on the soil containing high percentages of manganese, contain a more active oxidase than plants from soil containing little manganese; and whether the increased activity of the oxidase in the yellow plants brings about their etiolated appearance, by the actual oxidation of the chlorophyl, or for other reasons, cannot be positively stated at this time. An examination under the high power miscroscope of the cross-section of the yellow leaves, shows, however, that for the most part the chlorophyl bodies have been entirely destroyed. Further investigation it is hoped will throw more light on this subject.

SUMMARY AND CONCLUSIONS.

1. Some of the pineapple soils of Hawaii contain black spots on which pineapples do not grow successfully.

2. The application of fertilizers and lime in conjunction with good tillage and drainage, has not resulted in effectually overcoming the yellow appearance of the pines on black soil.

3. The black soils contain less acidity than the red soils.

4. There is but one important difference in the chemical composition of these soils, viz., in regard to the manganese content. The black soils contains many times as much manganese as the red soil.

5. The black color of these areas may in part be attributed to the presence of higher oxides of manganese.

6 There is a close correlation between the degree of yellowing of the pines and the percentage of manganese in the soil.

7. Yellow pines from soils containing a high percentage of manganese are more active oxidizing agents than green plants from red soil.

8. The yellow pines have a poor root system and contain but little chlorophyl.

9. As yet no positive remedy for this condition has been worked out. It seems wise to try other crops on the black soil, especially since sugar-cane grows well on the black soil.

This investigation is being continued along the lines suggested in the body of this bulletin. Acknowledgments are due Miss Alice R. Thompson, Assistant chemist, for assistance in this work. A large part of the analytical work was done by her, and many valuable suggestions were offered from time to time. Also to Doctor E. V. Wilcox for the microscopic examination of these plants, and for many very valuable suggestions. Thanks are also due the pineapple growers at Wahiawa for cooperation in this work.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 24.

A Preliminary Report on Cotton Experiments.

By F. G. KRAUSS.

Expert in Agriculture, Hawaii Experiment Station, United States Department of Agriculture.

The Hawaii Experiment Station has in progress investigations in the culture of cotton, of which this bulletin is a first report. Nine varieties or strains, representing three distinct classes, are under comparative test for yield, quality of lint, habits of growth and methods of culture. Considerable attention is being given to the selection of superior individual specimens, with a view to securing desirable mother plants from which to breed pure strains. It is believed that a method of propagation has been devised whereby the qualities of an individual plant may be perpetuated. Owing to the tendency of cotton to cross-fertilize, plants propagated by seed show more or less variability and any scheme which will tend to establish a uniform strain should prove a distinct aid in cotton breeding.

A systematic pruning experiment was begun as soon as the first crop was harvested, the general culture project including the test

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Hawaii has exceptionally fine climatic conditions for cotton. The increasing demand for cotton in the world's markets puts upon us the duty of adding to the supply. To grow the best cotton requires careful selection of seed. This cannot be done in the nurseries without danger of hybridzation. Fortunately, the effects of crossing can be easily avoided by the propagation of selected plants through cuttings. The present bulletin contains the first published account of this method as applied to cotton. By its use the cotton breeder will be able to accomplish results without danger of the mixing of strains by cross-fertilization.—E. V. Wilcox.

TABLE I YIELD OF VARIETIES OF COTTON, 1908 EXPERIMENTS. (1)

Test No.	VARIETY	SEED COTTON PER PICKING AND FOR TOTAL CROP. (Average Yield per Plant and Calculated to Acre Yields).											Per Cent. Lint	Total Yield Lint per Acre	Total Yield Seed per Acre	No. of Bolls per Pound Seed-Cotton	Length of Staple	Quality
		First Picking			Second Picking			Third Picking			Total Crop							
		Date	Yield per Plant	Yield per Acre	Date	Yield per Plant	Yield per Acre	Date	Yield per Plant	Yield per Acre	Yield per Plant	Yield per Acre						
			Ounces	Pounds		Ounces	Pounds		Ounces	Pounds	Ounces	Pounds		Pounds	Pounds		Inches	
100	Sea Island (Fla.)........	Aug. 8	4.6	1006	Sept. 14	.75	164	Oct. 12	.70	152	6.0	1322	31.0	409	913	102	1½ — 1⅞	**Exceptionally Good**
101	Sea Island (Ga.)	Aug. 8	7.1	1561	Sept. 14	2.4	466	Oct. 12	1.12	243	10.4	2270	31.0	703	1567	102	1½ — 1⅞	**Exceptionally Good**
102	Upland (Chinese)......	Sept. 12	7 0	(2)	Oct. 14	4.6	......	Nov. 5	3.75	......	15.4	......	34.5	......	......	96	⅞+	Very Fair
103	Caravonica (Wool).....	Oct. 16	3.7	805	Nov. 14	3.0	655	Nov. 25	.91	198	7.6	1658	33.0	547	1111	105	1¼ — 1½	Fair
104	Caravonica (Wool) ...	Oct. 31	3.2	(2)	Nov. 14	1.5	......	Nov. 30	1.56	......	6.3 (5)	.....	39.0	......	211	98	1½ — 1¾	**Exceptionally Good**
105	Caravonica (Silk)......	Oct. 31	2.9	(2)	Nov. 14	1.2	......	Nov. 30	1.11	......	5.3 (5)	......	33.0	......	193	100	1½ — 1¾	Fair
106	Caravonica (Wool) ...	...... (3)	44.0	1955	Aug. 8	30.4	1292	(4)	29.60	1258	104.0	4505	37.0	1667	2838	105	⅞+	Fair
107	Caravonica (Silk)......	...... (3)	30.0	1275	Aug. 8	20.0	850	(4)	20.00	850	70.0	2975	32.0	952	2023	109	⅞+	Fair
108	Caravonica (Kidney)	...... (3)	20.0	850	Aug. 8	19.6	833	(4)	18.00	765	57.6	2448	29.0	710	1738	105	¾+	Poor

(1) Tests Nos. 100 to 105 inclusive were sown March 9-30, 1908; tests Nos. 106-108 inclusive, were two year old plants at time of first picking.
Tests Nos. 100-103 inclusive, were planted 2½ x 5 feet apart or 3484 plants per acre; tests Nos. 104-108 inclusive were planted about 10 x 10 feet apart or 680 plants per acre.

(2) Owing to the limited number of plants under test the average yield per plant only is given.

(3) Harvested during the summer previous to August 8.

(4) After August 8 and up to November 30.

(5) A fourth picking on December 20th brought the yield of Test No. 104 up to 11 5 ounces per plant, and Test No. 105 up to 8.4 ounces per plant; all the plants except two in each test, were then pruned. The unpruned plants persisted in producing a few bolls through the remaining period up to March 30, 1909.

MICHIGAN STATE College
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of varieties as a perennial crop. In addition to the experiments conducted on the Station grounds, which are here reported in full, several cooperative experiments were conducted with interested parties in different parts of Oahu, the results of which are only briefly recorded. Beginning with the present year, two carefully planned experiments on a large scale were undertaken with private parties cooperatively, the Station supplying the seed, fertilizers and supervision.

That much local interest is being taken in cotton culture is attested by the application for seed and information, which has taxed the Station to the utmost. Seed has been distributed to about fifty applicants, representing many sections throughout the islands. Altogether, seed sufficient to plant about 200 acres has been distributed within the last twelve months and it is safe to say that at least 100 acres are planted to cotton at this time. While definite conclusions cannot be drawn from a single set of experiments, the present data may indicate some of the possibilities of cotton growing in Hawaii.

VARIETY TESTS.

Table I summarizes the results of the first year's comparative test of varieties. The Sea Island type of cotton is characterized by its long, strong, silky staple especially adapted to the manufacture of fine threads and mercerized goods. It brings the highest price of all cottons, ranging from 20 to 50 cents a pound, according to quality and supply. The demand is said to be constantly increasing, and while the market for the choicest grades at the highest prices is now rather limited, it does not seem likely that the amount that may be grown in Hawaii can materially affect the market.

As will be seen by referring to Table I, seed sown March 9th-30th, produced a first picking August 8th; a second, September 14th; and a third, on October 12th. The Florida strain yielded at the rate of 1322 pounds seed cotton per acre, equivalent to 409 pounds lint, or thirty-one per cent. The Georgia strain produced at the rate of 2270 pounds seed cotton, yielding 31 per cent fiber, or an equivalent of 703 pounds lint per acre. It should be noted that the first picking gave by far the largest yield, mainly because subsequent pickings became infested with the bollworm. The quality of the lint, the weights of which are recorded, was very choice, ranging from 1 1-2 to 2 inches in length and of good color and strength. Aside from that grown at the Station, an especially fine sample of lint was grown at Hauula from the same stock of seed. Concerning its culture the grower writes, under date of October 19, 1908, as follows: "The seeds were planted last April, on the edge of a marsh. The cotton sent you (13 1-4 pounds seed-cotton) is from about forty plants growing from six to eight inches apart and about six feet high. Much of the cotton was lost owing to the wind, and its late picking." This little test represents a very high yield, an average of five ounces per plant, from one picking, with plants set less than one foot apart. Another lot, grown at Waialee, gave similar results. A large area of land of this type is available for cotton culture.

Four different samples, submitted to D. N. Shoemaker, cotton expert, of the U. S. Department of Agriculture at Washington were rated as follows:

"Sample E*—Sea Island, (unginned), Florida Strain.
Color, white
Length, 1 1-2—1 7-8 inches
Strength, good
Drag, good
Covering of seed, good for Sea Island
Uniformity of lint, fair."

"Sample F†—Sea Island, Georgia Strain.
Color, white,
Length, 1 1-2—1 7-8 inches
Strength, good
Drag, good
Covering of seed, good
Uniformity, good."

The A. P. Brantley Company reported as follows: "We should say that sample H‡ has staple quite two inches in length, and is very strong, fine cotton. We consider sample G* to have staple 1 3-4 to 1 7-8 inches in length and is also fine and strong.

"We do not think there is any Georgia or Florida cotton in this crop to compare with this cotton. We should think that it would class more nearly with Fine or Extra Fine Islands. We notice that these two grades are quoted in Charleston, S. C., at 22 and 24 cents.

"It is quite difficult to estimate the value of this cotton, because it is in a class by itself."

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* Station Test No. 100
† Station Test No. 101.
‡ Hauula cooperative experiment.
* Waialee cooperative experiment.

Samples were likewise submitted to the cotton factors' association of Bremen, Germany, who made a most extended and favorable report, quoting 30 to 34 cents per pound for lots of sufficient quantity. Other reports have been similarly favorable and it would appear that there is an active demand for this quality of cotton at good prices. Compared with the yields, obtained in the Sea Island belt, the Station experimental yields, based on one-tenth acre plots, as well as those of smaller lots grown cooperatively, were very satisfactory. Authorities are also unanimous as to high quality of the fiber. It would appear that the samples grown on the windward side of the island directly facing the sea, have better conditions for producing the desirable qualities of length, fineness and strength of fiber.

The bolls of Sea Island cotton are small as compared with those of other types, averaging about 102 to the pound, which, together with the rather tenacious grasp in which the cotton is held, increases the cost of picking over that of other sorts. From 50 to 60 pounds of seed cotton per day was the maximum amount picked by a fairly active Japanese laborer, or, at the rate of about five cents per pound for lint. Experienced pickers could doubtlessly do much better.

At this writing (March 30, 1909), the second year's crop is well under way. Squares are forming in great profusion, and it is believed that the yield will average 50 per cent greater than that from the first year plants. After the third and final picking of the crop, in October 1908, seven months from seeding, the pruning experiment was begun in accordance with the following plan: Series I, plants cut back immediately after final picking, October 12th, prunings burned to destroy infested bolls; Series II, Plants cut back immediately following December rains; Series III, Plants cut back January 2, 1909; Series IV, Plants not pruned. Two types of pruning were adhered to under each series. In one type, the plants were cut back to within three or four inches of the ground, which is designated as type "A;" and in the other, the plants were pruned back to 12-20 inches, or equivalent to one-third to one-half their original growth, which has been designated as type "B." No laterals were permitted on the low pruned plants but spurs bearing two to four buds were maintained on the long pruned canes, if they were well located.

Most of the plants had shed the greater part of their leaves during the dry period following the last picking in October, and in consequence, remained quite dormant up to the first rains in December. However, the plants pruned immediately after harvest, especially those pruned low, were forced into fairly active growth almost immediately after being cut back. The different periods and types of pruning, together with the dry and wet seasons, are means for controlling the resting period of the plant, and within certain limits, the subsequent fruiting period and harvest of the crop. Thus, as was to be expected, drought and noninterference brought about partial dormancy, while on the other hand, pruning, irrigation and cultivation stirred the plant to renewed activity, apparently in direct ratio to the degree and sequence in which the several influencing factors were applied. The most marked results followed a combination of all the conditions named.

So far as these factors can be controlled, they will aid the grower in securing the strongest and most uniform plants; in determining the best seasons for maturity, from the standpoint of labor and prices; in the control of insect pests and diseases; and in obtaining the quality and quantity of product, which will determine success or failure.

From present indications, the best growth is secured from low pruning in January. Plants so treated are making the strongest and most uniform growth of wood, and appear to be the most prolific. Their season of ripening should prove much more favorable than that of plants pruned in October. The latter already show an occasional mature boll, as well as great irregularity in fruiting when pruned high. It should be remembered that the foregoing applies primarily, if not entirely, to the Sea Island cotton.

The qualities to be sought in Sea Island cotton are long lint (1 3-4 inch or longer), uniform staple, strength and drag of fiber, high percentage of lint, lustrous cream-white color, fineness, productiveness, well formed plants, long medium-large well filled bolls, and resistance to disease.

There is every indication that Sea Island cotton will adapt itself to culture as a perennial. The plants on the Station grounds are entering their second year in promising conditon. And as is well known, many stray specimens in the islands are five or more years old and still flourishing. A limited amount of Station grown seed is available for distribution.

Test No. 102 deals with an upland type of cotton of Chinese origin. The seed was procured from Mr. Ah Ai, to whom it was sent from China as of exceptional quality. The fiber is said to be used entirely for mixture with wool, and it is claimed, commands a ready sale at prices equivalent to about 40 cents American currency. As will be seen by referring to Table I this cotton gave the heaviest yield per plant of all varieties tested, sixteen plants approximating an average yield of one pound seed cotton per plant, equivalent to 1150 pounds of lint cotton per acre, if planted 2 1-2 by 5 feet apart.

The plants are dwarf as compared with the Sea Island type, of broad base and pyramidal form; very compact and of uniform growth; fruiting limbs branch frequently and occur at close intervals. The plant is an extremely prolific and continuous bearer. As grown at the Station during the past year, the plants were slower in maturing than the Sea Island, the first picking being made September 12th. An average of nearly 50 mature bolls per plant presented themselves at one time.

The locks were very easily picked and showed some inclination to shed when left too long. Nearly twice as much of this cotton could be picked in a given time as of Sea Island, the bolls in addition being somewhat larger and more easily reached. The percentage of lint to seed is larger than in Sea Island, averaging 34.5 per cent, but the fiber bears no comparison in length.

Concerning samples of lint of this variety submitted to Mr. Shoemaker, who judged the Sea Island samples, we have the following report:

> "Color, white
> Length, 7-8 inches
> Strength, good
> Drag, fair
> Covering of seed, fairly heavy
> Uniformity of lint, good."

"It would grade as 'very fair' American Upland in length."

The Chinese are said to claim for it unusual qualities of "warmth and feel," and because of these qualities, it is termed "fire" cotton, and should the demand and prices be satisfactory this variety may prove of special value in certain localities where Sea Island does not thrive. It seems drought resisting, and is believed to be hardy. The plant does not seem to be as well adapted to perennial culture as Sea Island, a number of the plants dying at the end of the first season. Several of the pruned plants, however, are making a fairly vigorous growth and may in time acquire the habit of persisting from year to year. The same general scheme of pruning as applied to the Sea Island cotton was adopted for this variety, but the limited number of plants available makes conclusions uncertain at this time. Samples of lint have been submitted to cotton factors in China and reports will be given to the press. A limited amount of selected seed is available for distribution.

The Caravonica cottons (tests Nos. 106-108), were grown from seed received from the originator in Queensland in 1905, by Mr. William M. Langton, who passed it on to the Station for trial. The seed was sown in July and is probably the first Caravonica cotton grown in Hawaii. Caravonica "wool," (test No. 104), and Caravonica "silk" (test No. 105), were grown from seed secured by Mr. E. W. Jordan from the originator in 1907.

The Caravonica class of cottons are of a comparatively new type, of hybrid origin, one of the parents unquestionably being the Sea Island with a probable admixture of the arborescent kidney type. The three strains designated by the originator as "wool," "silk" and "kidney" are characterized by their large, upright growth which assumes a tree form after the second year. The plant succeeds eminently as a perennial and three year old plants of the three types, grown on the Station grounds, show every indication of persisting indefinitely.

The heavy yielding power of this class of cottons is indicated in Table I, (tests Nos. 106-108). A conservative estimate of average yields from two year old plants, in a series of ten specimens, are 104, 70 and 57 ounces seed cotton per single plant, covering a period of approximately twelve months. This is equivalent to yields of 4505, 2975 and 2448 pounds of seed cotton, respectively per acre, with plants set 10 x 10 feet apart, which allows 680 plants per acre. The percentage of lint was 37, 32 and 29 per cent, respectively. The length and quality of the fiber had greatly deteriorated, but this was probably due to the entire neglect of the plants, which had not been tilled, irrigated or pruned for over a year. The plants appear to be responding to a severe pruning and it is hoped that the original quality may be restored by careful culture.

Test No. 103, a selection from the neglected plants in test No. 106, yielded a considerably better sample of lint than was obtained from the parent plants. The yields were fair considering that the habit of this class is to fruit late. The planting was made at the same distance as the Sea Island and Upland, which overcrowded the plants, doubtless to their detriment. The percentage of lint was not so high as in the parent stock, nor does the uniformity appear as good. This may be explained as being due to cross-fertilization, the three strains being planted in close proximity.

Mr. Shoemaker submits the following report concerning samples of this variety:

"Sample B—Caravonica Wool Cotton, 1908 Crop.
Color, slightly darker brown than A
Length, 1 1-4—1 1-2 inches
Strength, very strong
Drag, good
Covering of seed, fairly heavy
Uniformity of lint, only fair
Seeds many of them of the 'Kidney' type."

"This sample lacks a great deal of being uniform, and this is the one great fault of Caravonica cotton—it is a hybrid and one of the parents is a 'Kidney' cotton; that is, the seeds are all glued together in a mass in the center of each lock. The lint in this sample varies greatly in length, and the variation in the character of the seeds would probably make considerable difficulty in ginning."

Caravonica "Wool" (test No. 104), although planted at ample distances apart, yielded lightly, averaging 6.3 ounces seed cotton per plant up to November 30th, eight months after planting. A subsequent picking in December, just preceding pruning, brought the yield per plant up to the average Sea Island. Since however, the plants require at least twice as much room as the Sea Island, and Upland types, it will be seen that the yields would be smaller. The amount of lint is high, averaging about 40 per cent. As will be seen from Mr. Shoemaker's report, which follows, the quality of the lint is considered choice.

"Sample C—Caravonica Wool Cotton, 1908 Crop.
Color, much like first sample*
Length, 1 1-4—1 3-8 inches
Strength, very strong
Drag, good
Covering of seed, heavy
Uniformity of lint, fair."

"I think this sample is hardly so uniform as sample "A"; but otherwise, not far different."

As in the case of pruning the Sea Island cotton, this test shows the same general effects, i. e., late, low pruning tends to the production of a uniform growth of canes, together with unformity in fruiting. This report would be incomplete without a brief mention of the remarkable results obtained by Mr. E. C. Smith at The Peninsula near Pearl City. In a well sheltered spot, some thirty hills were planted to the identical stock seed sown in test No. 104. The ground is of a broken coral formation intermixed with a dry silty loam. It appears to be shallow, but papaias, bananas and other garden truck thrive with but little irrigation. The elevation is about ten feet above sea-level. Sown on January 6, 1908, the plants began bearing in August, and have continued to fruit almost uninterruptedly up to the present time. Careful test weighings from the three best plants, covering the first twelve months of growth, gave the following yields in seed cotton, averaging 40 per cent lint: 36, 40 and 48 ounces respectively.

Of this cotton, Mr. Shoemaker reports as follows:

"Sample A—Caravonica Wool Cotton, 1908 Crop.
Color, light brown, much like Egyptian
Length 1 1-2—1 3-8 inches
Strength, very strong, much stronger than ordinary cotton.
Drag, very good
Covering of seed, heavy
Uniformity of lint, good."

"This is a very beautiful sample of cotton, and I believe that if you could secure a field which would uniformly produce this grade, that it would be very much more valuable than any other sample submitted; in fact, more valuable than most of the Sea Island that is produced anywhere at present."

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* See report on Caravonica cotton grown by E. C. Smith.

Samples of this cotton have been submitted to American, English, French and German cotton experts, all of whom have made favorable reports, and prices ranging from 14 to 23 cents per pound have been freely quoted. It seems certain that this variety would prove of exceptional fitness to well sheltered lowlands. An extensive area is being planted, and definite data may be looked for at the end of another year. A cooperative pruning experiment is being conducted with Mr. Smith's plants. It appears that, under his conditions, high pruning, similar to that practised by California prune-growers, will give the best results.

CULTURAL NOTES.

Soil.—The experiments herein recorded were conducted at the Station grounds on a well drained, silty loam of fair depth and moderate fertility. The cotton plant appears to thrive best in light, rather than heavy soils, although thrifty plants abound throughout the islands on all kinds of soil.

Temperature.—The Station records show the minimum temperature, covering the period of these experiments, to have been 58° F. and the maximum, 86° F. The mean minimum was 64.5° and the mean maximum, 84.3°. The average temperature for the year was 73.0°. The Station grounds are at about 70 feet elevation. No data are at hand on the limits of temperature and elevation for the cotton crop in Hawaii, but it is hoped that the numerous plantings now made will shed needed light on this phase of the work.

Moisture.—The rainfall during the period in this report, approximated 30 inches. In addition to the natural precipitation, the cotton planted in March received three irrigations, all of which preceded May 1st. This brought the total moisture up to approximately 33 inches for the year. The total moisture supplied up to the first picking was something less than 20 inches. It is believed that the cotton plant, when once established, is tolerant to a lesser amount of moisture than most of our cultivated crops, and that it may be grown over a wide range of unirrigated territory by the aid of thorough tillage calculated to husband limited amount of soil moisture. The moisture in the Station cotton plots, as determined by the Station chemist, was found to be 14.06-17.51 per cent one foot below the surface during the periods of greatest growth.

Tillage.—Insufficient tillage was accorded the cotton plots during the earlier stages of preparation. After lying in undisturbed fallow for some months, the ground cracked badly through drought. A single plowing, followed immediately by a discing and cross-discing, preceded the planting of the seed. The short interval between breaking up the land and seeding was too short to prepare a suitable seed bed and bring about a conservation of soil moisture; and a preliminary irrigation had to be made to facilitate germination. Subsequent tillage was frequent and thorough, and although the season was unusually dry, two additional irrigations were found sufficient to carry the crop to successful fruiting. Tillage has been found to be a most important factor in the culture of cotton. Deep plowing, at least on our leeward uplands, where the nature of the sub-soil permits, would seem advisable. Storage room is thus provided for the conservation of all the rainfall; the deep rooted cotton obtains a good foothold and the feeding ground for the extensive root system is greatly enlarged. Frequent shallow surface tillage lessens evaporation by providing a soil or dust mulch; keeps the soil aerated; destroys weeds and avoids the harboring of insect pests.

Planting.—The Sea Island cottons and Caravonica "Wool" cotton (103) were planted in hills two and one-half feet apart in rows five feet apart, or 3484 hills per acre. Five seeds were planted in a hill, two inches deep. All but a single strong seedling were removed when the plants were six to ten inches tall. The Sea Island seed germinated very poorly and some destruction by cut-worms necessitated considerable transplanting to make a full stand. Transplanted seedlings never attain as good growth as plants from direct sowings, although sturdy seedlings may be successfully transplanted under favorable weather conditions.

With late plantings, or in localities with minimum moisture, it is recommended to plant the Sea Island and Upland cottons in four foot rows, hills two feet apart in the row. Early plantings in more favorable locations had better be planted 2 1-2 x 5 feet apart. Especially important is this wider spacing when the crop is grown as a perennial. In this case it will be necessary to remove every alternate plant the second year, making the final stand 5 x 5 feet, or 1742 plants per acre. Our Caravonica plants stand approximately 8 x 8 feet apart. This is too close for two year old plants under our conditions, 10 x 10 feet would be better; but for less favorable conditions, 4 x 8 feet apart for the first year, thinned out to 8 x 8 feet would give good results.

The Caravonica Nos. 104 and 105, were planted very wide apart, but would have yielded quite as well had they been planted closer. In calculating acre yields, 5 x 10 feet was used as the space factor. The results obtained with Caravonica No. 103 indicate that much closer planting would be feasible for the first year's growth, but more experience is necessary to prove this point. It has also been found that close planting acts as a protective measure against destructive winds, especially while the growth is young and brittle. The severe winds of November 28th and 29th failed to damage mature plants, while less severe winds at an earlier period badly shattered the Caravonica plants growing far apart.

To avoid the expense of hand tillage as much as possible, it is essential that planting be done in straight check rows at sufficient distances apart to facilitate horse cultivation. Planting may also be done with a horse seeder, but until seed becomes more plentiful, it will be more economical to plant by hand. The best season for planting has not yet been determined experimentally, but it is believed that as soon as the ground is in good working condition, after the first of January, and up to the first of March, cotton may be planted on the leeward side of Oahu. Planting later than March, unless the rainy season extends beyond that time, will likely result in the plants making a poor growth unless irrigation is provided. On the other hand, early planting should be avoided in excessively wet localities.

To a certain extent, the time of planting controls the harvesting period. The aim should be to have the crop mature at the most favorable season for picking, both from the standpoint of weather conditions and labor supply. During the past year the Upland cotton matured in six to seven months; the Sea Island in about the same length of time; and the Caravonica, from one to two months later.

Fertilization and Rotation.—The cotton plant is a strong feeder and it seems very likely that our most fertile soils may within a few years of cotton growing, respond profitably to a rational system of fertilization. A fertilizer experiment was attempted in connection with the Sea Island cotton during the past year, and while some benefit appears to have resulted from the application of 300 pounds per acre of a complete fertilizer; based upon the removal of an average crop of cotton, the unusual dry weather made the outcome too uncertain to form definite conclusions. We now have in progress a fertilizer experiment covering two acres.

That the rotation of other crops with cotton will prove beneficial, there can be no doubt. Experiments along this line are well under way; but it will require several years before definite data can be secured. Corn, soy beans, peanuts and other leguminous crops would enter well into a two or three-course rotation. In the southern United States corn and cow peas most frequently enter into rotation with cotton, although in the Sea Islands themselves, rotation is too often neglected.

Picking and Ginning.—Picking will probably prove the heaviest item of expense and one of the most difficult problems the Hawaiian cotton grower will have to meet, until the industry becomes adjusted. Tests made on a small scale at the Station indicate that a good Japanese laborer can not pick over fifty pounds of average Sea Island cotton per day of ten hours; possibly a fourth more of Caravonica; and at best, a hundred pounds of Upland, which is the easiest of all to pick. Greater skill would doubtlessly be acquired with experience. Even by piece work, the cost at present would probably run from $1.00 to $2.00 per 100 pounds seed-cotton, depending on the variety and yield.

The removal of the lint from the smooth seeded cottons, such as the Sea Island and Caravonica types, is done on the roller-gin to avoid injury to the long and more delicate staple. The more closely adhering and coarser Upland lint is removed on saw-gins, which also have greater capacity. Small machines of both types, are on the market; but a large central ginning plant would prove more economical when the area under cotton warranted its establishment. For experimental purposes, the Station uses a simple wooden contrivance of Japanese manufacture, which is well suited for the removal of seed from selected plants. Its cost is about $5.00. By replacing the rubber rollers on a wash-wringer, with wooden ones, a simple roller-gin of twenty or thirty pounds daily capacity could easily be made.

Seed Selection.—To the writer's mind the most important single factor in the future success of the cotton industry in Hawaii will be the development and maintenance of superior strains of the type of cotton which proves best suited to a given locality. Grade and quantity of lint are the chief qualities sought for in cotton, although the value of seed may in time prove equally important. These qualities are very largely hereditary, and as the plant is extremely variable, the opportunities for selection are correspondingly great.

The striking difference between individuals among a given lot of plants are well illustrated in our experiments with the Sea Island cottons. In row 4, of the Florida strain, the plants ranged from 24 to 60 inches in height; adjoining plants bore 30 to 120 bolls, and yielded four to 18 ounces of seed-cotton. The percentage and length of lint were somewhat more uniform, but differences in these respects were sufficiently marked to allow of considerable improvement by selection. Other qualities, such as early and late maturing, length of fruiting period, ease of picking, inclination to shatter, resistance to pests and diseases, all may be controlled to a large extent by careful selection. Some sixty selections of individual plants have been made during the past year from among the Station plants. These will be planted separately and selection made, generation after generation, a definite ideal being kept in mind. It will be well for growers to start out with the best seed obtainable, and then select rigidly their best plants for stock seed.

The seed from each mother plant should be sown separately and the progeny again carefully examined for breeding plants showing improvement. A single plant will yield 500 or more seeds the first year, and the progeny from this stock should produce sufficient seed to plant from ten to twenty acres the year following.

In the search for a method whereby the qualities of an individual specimen might be perpetuated, a scheme of propagation by layers or cuttings was hit upon. It was noted that the old Caravonica plants budded freely from the surface roots and as many as ten plants were secured from a single lateral by this method. This suggested that similar results might be secured from cuttings of the branches and a large number were made from immature wood. These gave indifferent results and a more systematic experiment was undertaken as the plants matured and were ready for general pruning. Accordingly, on December 15th, cuttings were made from a number of select plants, representing the three classes of cotton under experiment. Selecting the best formed and most fruitful branches, cuttings were made from the tip end, the intermediate portion and the base. Cuttings eight to ten inches long and containing five to eight eyes, were cut from each of the three divisions and planted in the field after the manner of rooting grape cuttings. The Sea Island and Caravonica cottons rooted equally well, about fifty per cent of all the cuttings planted rooting and making a satisfactory growth. The Caravonica root cuttings practically all grew, and are making a fine growth. The Upland cuttings failed entirely. With the Sea Island, the base cuttings rooted best, but with the Caravonicas, the tip cuttings gave the largest percentage of strong plants. With the Caravonica root cuttings, all portions were of about equal value. At this writing one hundred days from planting, the cuttings have grown from twelve to thirty inches in height. Squares are forming on some of the advanced plants, and the general growth compares favorably with stock grown from seed. It is believed that a larger percentage of cuttings can be made to grow under more favorable conditions.

Mr. E. C. Smith of Pearl City has demonstrated that it is feasible to propagate the Caravonica cottons by budding, and this method would likewise lend itself to furthering the work in hand.

The plan now is to grow any desired number of cotton varieties and strains in comparative tests and as individual plants are selected for breeding purposes they are marked. When the proper time for pruning arrives all available wood is utilized for cuttings. These are then planted in isolated plots and allowed to fruit. The resultant seed will be of a pure strain.

Should continuous inbreeding tend to the deterioration of a strain, some method of line-breeding, as successfully practiced by breeders of other crops, can doubtlessly be devised, the "ear-row" plan for the improvement of cotton being suggested as a feasible method. The important point is that we now have a simple method whereby the exceptional individual when once found may be propagated true to type.

Hawaii Agricultural Experiment Station,
HONOLULU.

E. V. WILCOX, Special Agent in Charge

PRESS BULLETIN NO. 25

Carbon Bisulphid for Killing Weeds

By E. V. WILCOX,
Special Agent in Charge, Hawaii Agricultural Experiment
Station, United States Department of Agriculture.

In the perpetual conflict with weeds it becomes necessary to make use of every weapon which shows efficiency in destroying them. The conditions under which different crops are raised indicate different methods as best adapted to the various conditions of each case. During the past year a number of experiments have been made with carbon bisulphid in studying its effects upon various herbaceous and shrubby weeds. In these experiments, the amount of carbon bisulphid used varied according to the size of the plant to be destroyed. On small-stemmed plants like *Crotalaria,* about a teaspoonful of commercial bisulphid was poured down the stem, from about six inches above the ground. The amount was increased, for larger plants, up to two tablespoonfuls for guava bushes three or four inches in diameter. The plants upon which most of the tests were made were lantana, guava, prickly-pear, *Stachytarpheta dicotoma* (one of the plants known by the native name Oi), and *Crotalaria incana.* In all cases, as just indicated, the carbon bisulphid was poured on the stem at a point about six inches above the surface of the ground. On most plants carbon bisulphid shows no effect until after the lapse of a considerable period; on large guavas sometimes two or three months. The effect of pouring carbon bisulphid on *Crotalaria* was to cause the death of the plant, root and branches, within four to ten days. The plants remain green, and apparently normal, until shortly before death, when the leaves suddenly turn yellow and shrivel up. If the plants are then carefully removed from the soil it is found that all of the root-system is dead and the inner tissues of the roots and lower part of the stem are brown, or otherwise discolored.

Lantana bushes, about two inches in diameter, died within seventeen to thirty-two days after the application of carbon bisulphid. About the same length of time was required for the destruction of Oi. Young prickly-pear plants, about two feet in height, were found to be exceedingly sensitive to carbon bisulphid. In some cases, the plants fell over on the ground within twenty-four hours after being moistened with the liquid; and in other cases, were dead within two days.

With guava, the effects of carbon bisulphid were not manifested for a much longer period, in some cases even not for two or three months. Finally, however, in all but two cases the leaves turned yellow, withered up, and the plant died. The dead and dying trees were dug out and the roots examined. In every case the roots were found to be dead to the tip and their whole tissue discolored. In one case, the guava tree was over six inches in diameter at the base.

Apparently, the effect of carbon bisulphid, when applied directly to the stems of plants, is due to artificial freezing. As is well known, the liquid volatilizes almost instantly and cools the surface so suddenly that the living bark is destroyed. It was found to be a simple matter to produce ice at noon on hot days on the surface of guavas and other plants by slowly dripping carbon bisulphid along the trunk. The death of large guavas from an application of a small quantity of carbon bisulphid to the base of the trunk, a few inches above the ground, can hardly be attributed entirely to the freezing effect. It seems also to exercise a poisonous action, otherwise it would be difficult to explain the complete destruction of the roots to

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their tips, in some instances, six or eight feet from the point where the carbon bisulphid was applied. It was found, for example, that guava bushes would live for five to seven months after the bark and cambium had been entirely removed from the surface of the ground up to a height of two feet. Moreover, the destruction of the bark at the base of the trunk by concentrated sulphuric acid was not sufficient to cause the death of the guava bush for about six months. Apparently, therefore, carbon bisulphid causes the death of plants by its freezing effect and also by a poisonous action.

The use of carbon bisulphid for destroying underground insects is a familiar practice. It may be interesting, therefore, to inquire what effect, if any, the extensive use of carbon bisulphid may have upon the soil and its adaptability to cultivation. It is well known, for example, that the application of carbon bisulphid to the soil around fruit trees and other plants has no injurious effect upon the plants; in fact, [1]Hiltner and Störmer have shown that carbon bisulphid reduces denitrification and the fixation of nitrogen. Similarly, [2]Heinze demonstrated that carbon bisulphid promotes the activity of nitrogen-fixing organisms. In experiments carried on by Nobbe, the yield of peas, and various other crops, was increased as a result of the application of carbon bisulphid and the plants absorbed more ash and nitrogen. [3]Henry found that when 400 cc. of carbon bisulphid per square meter was injected into the soil about locust trees, beneficial effects upon the growth of the trees were observed for several years. On the other hand, heavy fumigation with carbon bisulphid has frequently proved injurious or fatal to young fruit trees. In a series of experiments by [4]Oberlin, carried on for eighteen years, in treating grape *Phylloxera,* it was found that carbon bisulphid had a remarkable effect in increasing the yield of grapes. When other crops were rotated with grapes, for example, legumes, sugar-beets, and cereals, a considerably increased yield was also noted in these plants. In a few instances, it appeared that soil made "sick" by continuous culture of the same crop was restored to productiveness by the use of carbon bisulphid.

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[1] L. Hiltner and K. Stormer, Arb. K. Gesundheitsamte, Biol. Abt. 3 (1903) pp. 443-545.

[2] B. Heinze, Centbl. Bakt., etc., 2 Abt. 16 (1906) pp. 329-358.

[3] E. Henry, Bul. Soc. Sci. Nancy, 3 Ser. 2 (1901) pp. 27-33.

[4] C. Oberlin, Jour. Agr. Prat. 59 (1895) pp. 459-464, 499-503, 535-540.

Apparently the only previous experiments with carbon bisulphid, as a weed-destroyer, were carried out by Walker in Arkansas in destroying sassafras sprouts, and by the writer, in Maryland, also on sassafras. In both of these localities the chemical was found to produce the death of the plants within one month.

In using carbon bisulphid it should always be remembered that the fumes, if inhaled continuously, may produce serious effects upon the workmen, and also that the material is highly inflammable and should be protected from accidental flames. The effects of the fumes upon workmen include headache, dizziness, hysterical excitement, and, finally, a rather serious weakness, a feeble pulse and other symptoms of prostration. If it is used, therefore, in the eradication of weeds, these effects should be borne in mind in order to protect the workmen.

It is obvious that carbon bisulphid, although an effective means of destroying certain weeds, cannot be used economically in all localities. There are many steep slopes covered with guavas, in which it would be a very difficult matter to operate with this chemical. It is always necessary for the workmen to keep to the windward, in order to avoid the fumes, and in some localities the difficulty of transporting containers would render the method entirely impracticable. On the other hand, the use of carbon bisulphid in the destruction of such plants as the guava has the advantage that young sprouts do not come up from the roots. The necessity of grubbing out all of the roots is thus obviated. Under such circumstances, it would merely be necessary to allow the guavas to stand until they are dead, after which the trunk and large roots would be removed, as is necessary in any case in clearing the land.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 26.

The Algaroba in Hawaii.

By E. V. WILCOX,
Special Agent in Charge, Hawaii Agricultural Experiment Station, United States Department of Agriculture.

INTRODUCTION OF THE ALGAROBA.

The algaroba, or keawe (*Prosopis juliflora*), is commonly recognized as the most valuable tree which has thus far been introduced into the Territory of Hawaii. The accounts of its first introduction into the Territory are somewhat at variance. At the corner lot belonging to the Catholic Cathedral of Honolulu stands an algaroba tree which is supposed to be the first one introduced, and which bears a tablet stating that it was planted by Father Bachelot in 1837. In support of this tablet we find the following statement in an article on the "History of the Hawaiian Missions,"[1] referring to the second visit of Father Bachelot to Honolulu: "On his return from California he had planted in the Mission grounds four shoots of the algaroba tree, until then unknown in the Islands. Only one of these had taken root and was now growing fast. As the worn-down missionary left his mission house, never again to return to it, he looked upon the plant with moistened eyes and said as though prophetically: 'Even as this young tree by Divine Providence will thrive and cover the whole of the island with its shade,'" etc. Essentially the same statement was translated into French and subsequently published.[2] In the "Pacific Commercial Advertiser" for January 1, 1900, in an article by H. M. Whitney, we find the following statement placing the same date upon the first introduction, but attributing it to another man: "The algaroba—by far the most valuable tree on the Islands—was introduced by seeds brought from Chile by Bishop Maigret, and the first tree started by him is now growing in the north corner of the Catholic Church yard." A drawing of the Catholic Cathedral at Honolulu was made in 1842 and was subsequently published in Paris with certain notations. In this drawing the original algaroba tree is shown standing considerably higher than the Cathedral. This would obviously have been impossible if the tree had been only five years old at the time the drawing was made. Below the drawing of the Cathedral is a printed statement in French, which, translated, reads as follows: "Tree planted by Mr. Bachelot in 1828. It is a magnificent Acacia. The seed was brought from the Jardin du Roi de Paris." Father Reginald, Librarian of the Catholic Cathedral, has looked up all of the records relating to the introduction of the algaroba and considers 1828 as undoubtedly the correct date. He states in a recent letter to Father Valentin that in 1837 there were already several algaroba trees from the seed of the first one. Moreover, the statement in the previous quotation, that the original tree came from a shoot imported from California, may be considered as somewhat doubtful on account of the difficulty of propagating the tree from shoots, except under favorable conditions. Shoots brought by sailing vessel from California would, ordinarily, not be in good condition for planting upon their arrival.

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[1] Damien Institute, Vol. 12, 1903, No. 12, pages 190 and 191.

BOTANY AND HABITAT.

There are eighteen or more species of *Prosopis,* the natural habitat of which is in tropical and semi-tropical America. The algaroba occurs from Texas to Chile and in the West Indies.

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[2] Ann. Sacres Coeurs, 1896, pages 288-290.

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Another species (*Prosopis glandulosa*), known also as the Texas mesquite, is found alongside of the algaroba in Texas, and there are a few trees of this species on Molokai. Seeds from these trees have also been planted in other localities. If we accept as true the statement that the original seeds were brought from Paris by Father Bachelot on his first trip to the Islands, it is impossible to determine their exact origin. The tree is, of course, not native in France and the seeds must have been brought there from some other locality.

The distribution of algaroba in Hawaii is largely determined by the rainfall conditions. The tree thrives best in dry localities, and is somewhat sensitive to salt air. Nevertheless, on the windward side of Lanai there is a fine belt of algaroba which extends to within a few hundred feet of the seashore. The trees which grow nearest the water on the leeward side of the Islands, sometimes have the leaves destroyed by salt spray during Kona storms, but recover later, showing little effects from the salt water. Algaroba thrives best at low altitudes, but is everywhere gradually extending to higher levels, and it is found in some localities at altitudes as high as two thousand feet. Apparently, it is gradually becoming acclimated to the higher altitudes, but it bears most abundantly at lower levels. Considerable attention has been given to the distribution of this tree in carrying it from one island or locality to another, but, on the whole, its distribution has been largely accomplished by stock. Practically all of the islands have enormous belts of algaroba forest, extending from the sea-shore, on the leeward side, up to an altitude of 800 or 1,000 feet.

USES OF ALGAROBA.

There are few trees which are distinctly useful for more purposes than is true for the algaroba. Its flowers furnish the most important source of pure honey known in the Territory. The bee-raisers of the Territory have shown an active interest in securing the rights of placing apiaries so as to utilize to the fullest extent the algaroba forests. The yield of honey is recognized as large and important, and occurs at two seasons, there being two crops of flowers and pods annually.

As a forage crop algaroba is of far greater financial value. The pods are everywhere recognized as one of the most important grain feeds of the islands and are greatly relished by all kinds of live stock, including chickens. The quantities of pods produced by the algaroba forests cannot be estimated, even approximately, for a large proportion of the pods are allowed to fall on the ground and are eaten by cattle, hogs and horses, without being previously picked up. It has been estimated that approximately 500,000 bags of the beans are annually picked up and stored, particularly for feeding horses and cattle. On two or three estates at least 15,000 bags of beans are annually stored for this purpose.

Algaroba wood also constitutes one of the best and chief sources of fuel in the Territory. Its growth is comparatively rapid and the larger trees can be removed for fuel, thus making room for the growth of another generation of trees. In addition to these uses of the algaroba, it might also be stated that the bark contains tannin, and the gum is suitable for use in varnish. Being a legume, and of remarkable penetrating power in the soils, it is also a soil-maker of some importance. As a shade and ornamental tree it is highly appreciated. The form of the tree is graceful and spreading. The small branches furnish excellent material for making charcoal. Piles made from algaroba are relatively free from the attack of the Toredo. Moreover, since the pods contain a high percentage of sugar, they may be used in the manufacture of denatured alcohol and vinegar.

ALGAROBA BEANS AS STOCK FEED.

The algaroba is chiefly interesting on account of the enormous quantity of forage which the beans furnish. As already stated, all kinds of farm stock are very fond of them, and their feeding value has long been recognized from the practical results obtained. As a feeding material there seems to be only one objection to them, and that is, a slight flavor given to milk when the beans are fed in excess to the dairy cows. This objection, however, could be overcome by feeding the beans after milking, rather than before milking. The whole pods of the algaroba show the following percentage composition: Water 15.26, protein 8.89, fat .58, nitrogen free extract 47.27, crude fibre 24.75, ash 3.25. The seeds alone, however, have the following percentage composition: Water 14.38, protein 33.62, fat 3.94, nitrogen free extract 36.78, crude fibre 6.84, ash 4.44. It has long been known that on account of the hard case, like that of a shark's egg, surrounding each seed, the seeds themselves are not digested by live stock. On this account, if the pods are fed whole, the protein content is largely lost and the pods do not furnish a ration so well balanced as would be the case if the seeds were rendered digestible.

Realizing the great importance of algaroba beans as a forage, a number of persons made attempts to grind the pods, in order to crack the beans, and thus render them available as food. Mr. Paul Isenberg spent a great deal of time and money in this experiment, during which confident promises of success were made by mainland millers, without ultimate success. Similarly, Mr. F. G. Krauss of this Station, while connected with the Kamehameha Schools, had experiments made by six or more mainland concerns who at first believed that some of their mills, designed for grinding drugs and miscellaneous materials, would successfully meet the problem of grinding algaroba beans. All their tests, however, proved that the machinery then in use was not adapted to grinding the algaroba. The difficulty in the way of grinding the beans is furnished by the large amount of sugar in the pulp of the pods. This sugar is in essentially the condition of molasses and gradually accumulates on the milling machinery, forming a layer resembling vulcanized rubber in consistency, and ultimately causing a heating of the machinery so that it has to be stopped. The cleaning of mill machinery which has once been coated with this layer is a very tedious and difficult operation.

Two years ago this Station began experiments in grinding algaroba beans and soon came to the conclusion that special machinery was needed for this purpose. It was found that various milling machines would successfully do the work for a few minutes, or perhaps for half an hour, but that ultimately the coating of moistened sugar on the machinery rendered further operation impossible. It was found, however, that the addition of a very small quantity of water to the cracked pods was sufficient to render the sugar in the pods no longer sticky. The extraction of a portion of the sugar, by means of water, makes it possible to dry the cracked pods in a condition in which any feed-grinder will successfully crack the seeds. The removal of a portion of the sugar, however, takes away some of the feeding value of the beans and renders an alcohol or vinegar plant necessary in order to utilize the sugar thus extracted. The desirability of special machinery, which would successfully crack the beans in fresh, untreated pods, became therefore more and more apparent. Finally the interest of a trained mechanic and inventor, Mr. C. W. Renear, was enlisted, and after several months of experimenting, he succeeded in devising a machine which would grind the fresh beans, cracking all of the seeds, and thus rendering them available for stock. The feeding test made by this Station showed that the seeds thus cracked are completely digested by horses, mules and cattle.

In repeated tests with the algaroba bean meal, just referred to, it was found desirable to adopt the suggestion made by this Station as to the advantage of a minute spray of water to prevent the sugary material from adhering to the roller of the mill. After this device was adopted, no tendency was shown for the sugar to adhere, and the roller remained perfectly clean. The amount of water added in this process is altogether too small to endanger the keeping qualities of the meal. The sugar in the pods does not ferment unless considerable water is added. The keeping quality of the meal is quite sufficient for the ordinary demands of the trade. When kept in sacks or open containers it retains its original odor and flavor, without change, for six or eight months, and the meal is no more subject to the attacks of insects than is any other grain feed.

On account of the prevalence of weevils, which attack and destroy the seeds on the tree, or after the pods have fallen off, or have been stored in bins, it was thought desirable to attempt the introduction of parasites to control these weevils. The Bureau of Entomology of the United States Department of Agriculture very kindly consented to cooperate with this Station, and Dr. W. D. Hunter made several shipments of mesquite beans containing parasitized weevils from Texas. The parasites were bred from this material in large numbers by Mr. D. T. Fullaway of this Station, and were subsequently liberated on Maui and in several localities near Honolulu. It is too soon yet to speak of the success of this introduction, but if subsequent investigation shows that the parasites have not become established, further introductions from Texas will be made during the coming season.

When it is considered that women and children pick up the beans and sell them for from $7.50 to $10.00 a ton, it is apparent that this feed has a much higher feeding value than its actual market price, particularly when compared with the high price which must be paid for imported feeds. The dairymen and ranchmen recognize the importance of feeding large quantities of the beans picked up for storage, in order to prevent the great loss which would occur if they were all left upon the ground. Wherever the belts of algaroba timber are large it has been found possible to maintain stock for a month or two of each season without any other forage than algaroba beans. Some of these belts, however, have been allowed to grow up much too dense. Under such conditions the individual trees remain too small and the yield of beans is less than would be the case if the trees were thinned out, so as to give a chance for each tree to spread to its full limit. The thinning process would nearly, if not quite, pay for itself in most localities in the fuel which would thereby be obtained. With the successful mill, which is now available for grinding algaroba, the feeding value of this already important natural forage asset of the Territory will be greatly increased.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 28.

PEANUTS IN HAWAII

BY

F. G. KRAUSS,
AGRONOMIST

The peanut is an annual plant. Two more or less distinct types are in general cultivation. Under Hawaiian conditions, the "bunch" type grows into an erect, compact bush 8 to 24 inches high with an equal spread of foliage; the "running" or "flat" type is decumbent and spreading, rarely more than a foot high, and in some varieties attains a spread of fully 5 feet in diameter, depending on variety and cultural conditions.

The fruit is not a nut but a ripened pod with edible seeds, not unlike the pea and bean. The prominent yellow infloresence are the male (staminate) flowers, the female (pistillate) flowers are hidden in the axils of the leaves. After fertilization has taken place the male flowers shrivel and fall away, while the female flowers rapidly develop into the rudimentary fruit on the end of an elongated stem. This soon turns downward and burrows into the ground, where it matures its so-called nuts. From experiments conducted by the Station, the peanut would seem to deserve extensive planting in Hawaii. Except for an occasional small planting made by Chinese and Japanese gardeners, very little has been done to develop it as a field crop. In the southern states the peanut is prized among the most valuable crops, combining, as it does, the desirable qualities of several important farm crops. The portion above ground makes a superior hay for horses, cattle and sheep, while the underground portion yields the nuts, which, acre for acre, is said to be more nutritious than the best corn or root crop that could be grown on the same type of land. The crop may be pastured, cured as fodder, or harvested with a view to disposing of the nuts as a money crop. Being a leguminous plant, it builds up the land through its power to utilize atmospheric nitrogen. Its roots are nearly always well supplied with the nitrifying bacteria nodules, an indication that the plant is performing this valuable function. For this reason and because it is a tilled crop, which leaves the soil mellow, it is well adapted for rotation with other crops. Furthermore, the crop grows with a less amount of moisture and on lands too sandy for corn and some other of the more common Hawaiian forage crops.

Recognizing the possible value of the improved peanut to Hawaiian agriculture, this Station in 1908 imported from a leading grower in Virginia 150 pounds choice seed of the following varieties: Spanish, Bunch Jumbo, Running Jumbo, and Virginia Creeping. These are illustrated in their natural size in Plate I. The seed was widely distributed over the islands and a number of favorable reports were received showing that the peanut would thrive over a wide territory. The best results appear invariably to have been obtained on light soils with moderate moisture. Heavy soils and wet locations proved in most cases unsuited. These results have been largely confirmed in the Station experiments, although fair yields and a fair quality of nut have been obtained on the medium heavy and moist mauka lands of the Station, and under similar conditions in Kalihi and Manoa valleys on Oahu. But the nuts grown under such conditions are always more or less discolored.

The following table summarizes the results obtained by the Station in small plantings and in more extensive co-operative experiments with outside growers.

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TABLE I.

SUMMARY OF YIELDS OF PEANUTS OBTAINED FROM STATION AND COOPERATIVE EXPERIMENTAL PLANTINGS FOR THE YEARS 1908, 1909, 1910.

Variety	Calculated to average acre yields			Highest Acre Yield (pounds)	Lowest Acre Yield (pounds)	Days to Maturity
	Green Weight Whole Peanut (pounds)	Cured Weight Nuts (pounds)	Cured Weight Tops (pounds)			
Spanish	10,454	1,728	1,835	3,858	564	168
Bunch Jumbo	8,961	1,881	1,950	3,225	837	158
Running Jumbo	14,439	2,077	2,256	4,729	675	158
Virginia Creeping	*	2,063	2,205	2,489	920	157
Bunch Virginia (Sport)	16,803	2,249	2,714	4,130	832	173

* Data not available, but the yields are known to about equal those of the Running Jumbo variety.

The yields of nuts are compiled from eight crops grown during various seasons covering three years, under widely different cultural conditions. The yields of green matter are taken from a single planting at the Station grounds during the present season and do not represent a high average. The yields of cured tops are an average of two crops, one very low, owing to loss of the valuable leaf portion, through weathering, and the other of a good average yield. In the Southern States the yield of peanut hay per acre frequently exceeds two tons. The highest yield recorded by this station is 3,370 pounds of cured tops from Running Jumbo planted in rows four feet apart.

These yields for the most part compare favorably with the best yields obtained in the leading peanut-growing districts of the South, notably the districts in Virginia and North Carolina, where the Station obtained its original seed.

No better proof of the adaptability of the peanut to favorable Hawaiian conditions could be given than to indicate its improvement under several years local culture. The following table gives the average number of peanuts in a pound of the select, originally imported seed stocks in comparison with the Hawaiian-grown nuts after three years' selection:

TABLE II.

AVERAGE NUMBER OF PEANUTS IN POD PER POUND.

Variety	Original seed as imported.	Hawaiian grown seed in third generation.
Spanish	759	444
Running Jumbo	345	232
Bunch Jumbo	352	226
Virginia Creeping	325	245
Bunch Virginia (sport)	....	228

It will be noted that in all varieties there were considerably more nuts per pound in the original seed than in the Station-grown stock. This would indicate that the Hawaiian-grown seed has increased materially in weight over the imported seed. It should be further noted that this increase in weight is not due to an increase in size of the pod, but rather to larger and heavier kernels, which is of far greater importance. The well-filled pods of the several varieties of the Hawaiian-grown nut is well shown in Plate I. This is in marked contrast to the poorly-filled and frequent "pops," (empty pods), met with in the exceptionally large pods of the Jumbo varieties during our earlier experiments. In selecting for seed, growers are cautioned to avoid selecting the extra large pods, which, while they are of fine appearance, frequently bear poorly-developed kernels. Well-filled pods of medium size give much better satisfaction in both yield and quality of product. Not alone are the kernels of the Hawaiian-grown nut large and heavy, but also is the tonnage yield and quality high.

The following are the average yields per plant of sound, well-matured nuts taken from a large number of select plants used for breeding purposes: Spanish, 145; Bunch Jumbo, 184; Running Jumbo, 208; Virginia Creeping, 219; and Virginia Bunch, a sport selected from among the first generation of imported Virginia Creeping, 190. Numerous selections of Virginia Creeping having yielded 250 and more sound nuts. The green weight of such plants has averaged something over 10 pounds each, and the cured pods have run about 250 seeds per pound as against 325 pods per pound of the imported stock. A single plant of the sport, Bunch Virginia, has yielded 280 nuts, weighing one pound and three ounces.

Plate II illustrates a specimen plant of each of the five varieties considered in this bulletin and gives some idea of their heavy fruiting under favorable conditions. Taken one season with another, the Virginia Bunch, Virginia Creeping and Spanish have given the most uniformly good results from Station plantings, although in one or two instances the Jumbo type appears to have out-yielded either of the other sorts.

While the Jumbo and Virginia types resemble each other very closely in habit of growth and size and shape of nuts, the Spanish type is entirely distinct. Instead of the large, rank growth of foliage, and large nuts which characterize the other varieties, the Spanish is a very much smaller and compact grower, bearing practically all its small, well-shaped and closely-filled pods in a compact cluster centered about the tap root. This is much less common in the bunch variety of either the Virginia or Jumbo type, but totally absent in the running varieties, in which the peanuts are distributed along the entire length of the recumbent stems.

In general, it may be said that the nuts of the bunch varieties are much easier harvested than in the running kinds, and this in itself recommends the type for culture where the crop of nuts is the principal object. Being small, sweet and well flavored, the Spanish nut is preferred by confectioners. But to eat out of hand the large bunch varieties are more attractive and more sought after by the local dealers, except the Orientals, who prefer the smaller variety. The running or flat varieties, such as Running Jumbo and Virginia Creeping, while they yield prolifically a large fine nut, would seem best adapted for fodder and green manuring. Under favorable conditions they produce a large amount of vegetable matter, as is indicated in Table I, which exceeds in quantity and nutritive value almost any other crop that can be grown on light soils with an equal amount of moisture. In addition to which, both the physical and chemical conditions of the land are improved for succeeding crops of corn, cotton or grain.

PLANTING AND HARVESTING.

In addition to a thorough preparation of the land before planting, frequent shallow cultivation to suppress weeds during the earlier growth of the crop, and to keep the ground mellow, but not too loose, are very essential to the best success. A sandy or light gravelly loam seems best adapted to the full development of both nuts and vines, although a heavy growth of the latter usually results on heavier soils when well drained and tilled. Another important advantage of light soils is the avoidance of discoloring the pods which is likely to occur in dark or red soils especially when inclined towards clay and an over-supply of moisture.

The large-growing bunch varieties should be planted in rows 3 to 3½ feet apart. The running varieties require more room, 3½ to 5 feet between the rows being the best distance as indicated in our experience. The Spanish variety may be planted in rows 2 to 3 feet apart. We plant 2 seeds per running foot of row for all varieties, which has proved entirely satisfactory. It should be here noted that in the experimental plantings all test rows are placed 5 feet apart and the comparatively low yields of the Spanish peanut shown in the table of acre yields is due to this fact; placing the rows 2½ feet apart would in most cases almost double the yield. Planting is best done by running shallow furrows at proper distances apart. A six- or eight-inch mould-board plow set to run not over 4 inches deep will answer the purpose admirably, or the drills may be made with a hoe. Drop the seed by hand and cover 1 to 3 inches deep, according to type of soil and moisture; light, dry soils requiring the deeper planting. If very mellow, the soil should be firmed above the seeds, a light roller or the feet answering the purpose well. If only a small quantity is to be planted the seed had better be shelled, as nothing but perfect kernels may then be selected. Owing to the tedious operation of shelling the nuts, in extensive plantings it may be more practical to merely break the pod in two, or they may be planted whole, in which case the germination is somewhat slower, but otherwise satisfactory if sound nuts are used. Unless several acres are to be planted, it will probably not pay to purchase a planting implement, although these are not expensive and are said to do excellent work. The ordinary corn-planter may also be adjusted to do satisfactory planting.

The young plants must be kept free from weeds and should be frequently cultivated. If a hand wheel-hoe, such as the "Planet, Jr." or the ordinary one-horse five-tooth cultivator with proper attendants, is used in season, little or no hand-hoeing will be necessary. After the plants begin to flower they should be disturbed as little as possible. Unless the season turns very dry, the vines remain a deep-green color almost up to the time of harvest and it is well to pull a vine from time to time to determine the stage of maturity. While they should not be harvested too early, permitting the nuts to remain in the ground after a certain stage, especially if the season is wet, is taking a risk of losing part of the crop through the germination of the more mature and best seed. It appears to be impossible to permit the late-maturing nuts to ripen in the ground and at the same time save those maturing early, unless the soil and season are exceptionally favorable, and no set rule can be given when to harvest. It requires 140 to 170 days for the crop to mature under ordinary conditions. As early in the spring as the ground can be made friable is the best time for planting. As large a part of the nuts as possible should be permitted to mature underground and then harvested with vines attached, in which condition they may be cured, either in tall slender shocks made by stringing the plants on a pole driven upright in the ground, out of doors, or hung over lines in a well-ventilated shed.

When fully cured the nuts are picked off the vines and sorted. These latter operations are the most tedious in the whole production of the crop and unless done by cheap and skillful labor may consume most of the profits. In this connection, as well as in general methods and results, the experience of the writer, who grew privately, in 1908, a third-acre of the four varieties under consideration may be of interest.

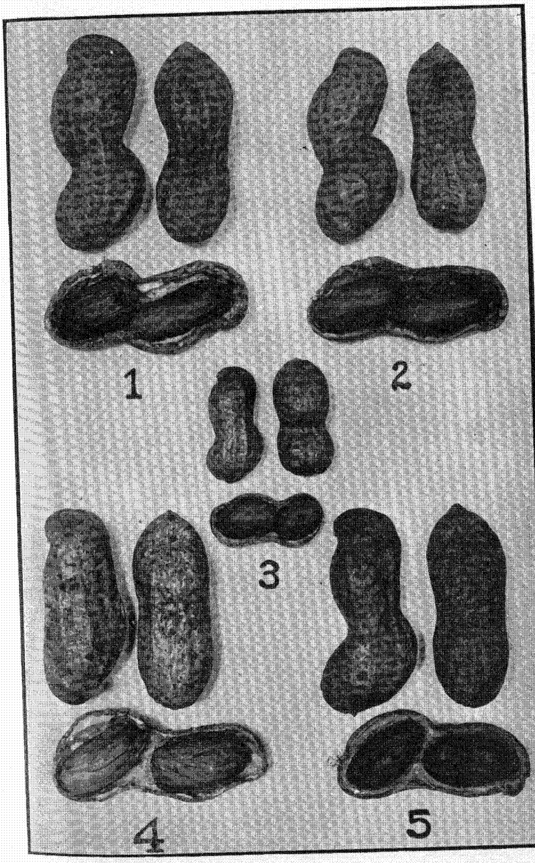
Planted in the Manoa Valley in a well-prepared virgin soil of a medium gravelly loam, which was covered with a heavy growth of guava the previous year, the crop grew luxuriantly and proved of easiest possible culture. By using select shelled seed, strong germination and a full stand were obtained. The crop was planted in July. Two seeds were planted in a hill, a foot apart, in rows 4 feet apart. This permitted of horse-cultivation up to the flowering stage, after which the crop received no further attention until harvested. The general crop matured in about 150 days, the Spanish variety matured somewhat earlier, but all varieties were dug at the same time. Harvesting was facilitated by loosening the plant with a broad-tined spading-fork thrust under the hill, which permitted pulling out the plant with practically all the nuts adhering. Calculated to acre yields, the following results were obtained: Spanish—1,965 pounds nuts, 2,550 pounds cured tops; Bunch Jumbo—1,450 pounds nuts, 2,925 pounds cured tops; Running Jumbo, 1,680 pounds nuts, 3,370 pounds cured tops; Virginia Creeping—1,760 pounds nuts, 3,150 pounds cured tops. In this experiment, the two Jumbo varieties gave the smallest yields of nuts, due to the fact that the fine large pods consisted of a large percentage of "pops" (empty pods). Excellent as were these fields, there can be no question but that a considerably increased yield would have resulted from closer planting,—for the Spanish variety, say 2½ feet, and the other varieties 3½ feet apart. The crop sold readily at 6 cents per pound except the Spanish variety, which was sold in part at 5 cents per pound, and the balance was retained for home use in preference to any of the other varieties. The cash value of the nuts calculated to acre yields alone was as follows: Spanish, $98.00; Bunch Jumbo, $87.00; Running Jumbo, $100.80; Virginia Creeping, $105.60. The cost of production up to the time of harvest did not exceed $20.00 per acre, but the cost of stripping the nuts from the vines and sorting them afterwards amounted to almost 2 cents per pound, or an average of approximately $35.00 per acre. This makes a total cost of about $55.0 per acre to place the crop in bags ready for market. Doubtless this expense would be materially lessened with a more extended experience, especially if women and children could be employed for the lighter but more tedious work of picking and sorting the nuts. In the above estimates no credit has been allowed for the cured tops. These gave an average yield of approximately 1½ tons of cured fodder per acre. At a low estimation these should be worth $12.50 per ton, or an added value of $18.75 per acre, about the cost of producing the whole crop up to the harvest stage. Numerous reports of the profitable culture of the peanut for home use have come to the Station. The Kamehameha Girls' School recently reported harvesting 93 pounds of sound nuts, from a piece of ground 26 x 50 feet square. This is equivalent to over 3,000 pounds of nuts per acre. While the work of stripping the nuts was found the most difficult part of their culture, here as elsewhere, it was in this case overcome by student labor, a suggestion for the utilization of our large population of school youth during vacation periods. To those acquainted with wholesome and profitable employment created by the lighter work about the orchards, vineyards and hop-fields in California and elsewhere, this suggestion will not seem impracticable. One of our prominent citizens has suggested this as a possible solution of the labor problem in picking cotton, should that industry become established in the islands, and the same service could doubtless be utilized in other ways.

USES OF THE PEANUT.

Some of the principal uses of the peanut have already been touched upon. At first thought the cash value of the nut crop might be considered of greatest importance, but in Hawaii, where the cost of nitrogenous feed-stuffs is exceptionally high, and in great demand, the fodder value of the plant, including the nuts, may prove more valuable than for any other purpose. With live hogs at 10 cents per pound, as at present, and for a decade past, there would appear to be more profit in feeding the crop to hogs than in disposing of the crop in any other way. The Alabama Experiment Station found that hogs run on peanut pasture produced a pound of pork on the following amounts of grain: Peanuts, 1.77 pounds; cow peas, 3.07 pounds; sweet potatoes, 3.13 pounds; sorghum, 3.70 pounds. The Arkansas Station reports that one-fourth of an acre planted to peanuts produced 313 pounds of pork as compared to 109 pounds from a plat of the same size planted to corn. Many other results could be quoted to show the superior feeding value, pound for pound and acre for acre, of peanuts over any other feed that can be grown where peanuts thrive. Analyses show peanut hay to have a higher feeding value than California wheat hay, and approaching that of alfalfa. In the South it is extensively fed to horses, mules, cattle and sheep, and milch cows respond to the ration, while all kinds of poultry relish both the fodder and seed. The advantages of feeding the crop on the farm are two-fold. In the first place, the large item of expense in picking and grading the nuts is eliminated, and secondly the valuable by-product, manure, is retained for further enriching the land.

As human food the peanut is constantly gaining in favor, and forms a regular article of diet in many households. Peanut butter is a staple article of commerce and is highly recommended by many physicians. Every kitchen garden should contain a small patch of peanuts for home consumption. The soil will be left in better condition thereby than if left fallow and run over with weeds. It is one of the few crops grown by the Station not excessively attacked by insect pests.

HAWAIIAN GROWN PEANUTS
(Slightly less than natural size)

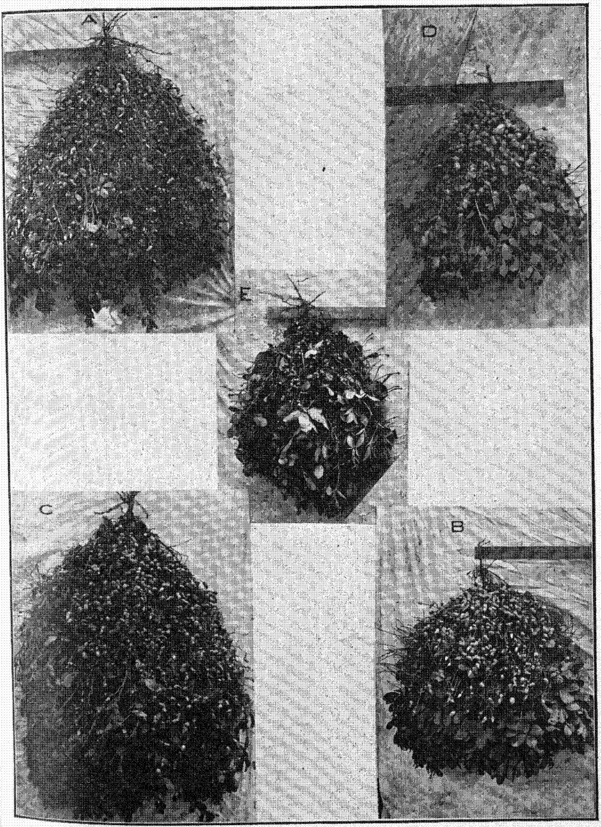


1.—Running Jumbo
2.—Virginia Creeping
3.—Spanish
4.—Bunch Jumbo
5.—Virginia Bunch

PLATE II.

A.—Virginia Creeping

D —Virginia Bunch



C.- Running Jumbo

E.—Spanish

B'—Bunch Jumbo

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 29.

The Management of Pineapple Soils

BY

W. P. KELLEY,
CHEMIST

INTRODUCTION.

The cultivation of pineapples in Hawaii has developed during the past fifteen years into one of the important agricultural industries of the islands. This crop for the most part has been grown on virgin soils, which produced large yields of excellent fruit, and this naturally encouraged a rapid expansion of the industry. While a small part of the land is owned by the grower, by far the greater part of the crop is grown on leased land. From the beginning the pineapple growers have been controlled largely by the idea of getting out of the land maximum crops at a minimum of cost, and with little forethought for the permanence of the industry or the maintenance of the soil. Pineapples constitute practically the only crop that is cultivated on these lands. The continuous growing of any one crop on the same soil is likely to be attended with certain difficulties and can hardly be said to belong to a system of permanent agriculture. The more especially is this true when it is applied to soils containing large percentages of finely divided ferric hydrate and small amounts of humus; soils that under the prevailing conditions naturally require the most intelligent management. There need be little cause for surprise, therefore, that conditions have arisen which at the outset were unsuspected and which are hindrances to the continued welfare of the industry.

A large part of the pineapple crop is grown on the upland plains of Oahu, principally in the Wahiawa and adjacent districts. The discussion in the following pages has been drawn largely from observations and a study of the conditions and soils in the Wahiawa district, although the deductions apply equally well to similar soils throughout the islands.

As pointed out in previous Annual* Reports of this Station, pineapple soils have been the subject of investigation at the Experiment Station for more than two years. In 1909 a preliminary report† was issued in which it was pointed out that the pineapple soils of Oahu may be divided into two classes as regards color—viz., black and red soils. In this report some of the peculiarities of the black soils were emphasized. Since then each of these classes of soil has been under continued investigation, which has resulted in the bringing together of a large amount of scientific data. In the present bulletin it is purposed to present the more practical phase of this work in so far as it relates to the management of the red soils. What follows, therefore, has no reference to the black manganiferous soils. The failure of pineapples there is due to altogether different causes.

THE CONDITIONS IN THE FIELDS.

For some time the growers have realized that in some way not definitely understood by them, their soils after a few years of cultivation begin to show indications of exhaustion. In general the first crop and the one or more rattoons following it are

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* For the chemical composition of these soils, see Hawaii Sta. An. Rept. 1909.

† Hawaii Sta. Press Bul. No. 23.

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quite satisfactory, but subsequent plantings result in diminished harvests. As already pointed out, pineapples constitute practically the only crop that is cultivated on these soils. Before replanting a field it is customary to haul off and remove all of the old plants, thus taking from the land every vestige of plant residue produced thereon. From 15 to 24 months being required for the production of the first harvest, followed by one, two or three rattoon crops of one year each, makes necessary the continued cultivation of the land for three or four years. Generally the virgin soil is porous and naturally absorbs and drains away excessive rains before the water becomes stagnant in the soil, and brings about a water-logged condition. After the virgin soil has undergone the necessary preparation to insure good tilth, it is granular and porous. It has what the farmer calls a shotty texture.

After a few years cultivation, however, there is brought about a noticeable difference in the appearance of the soil. It loses its granular texture, tillage becomes more difficult and natural drainage is retarded. Following a heavy rain the soil becomes compact, and dries out into a hard mass which, unless it is cultivated before thoroughly drying out, becomes almost solid. The same condition may be brought about even during the early growth of the first crop by an overflow of the ditches during excessive rains, which frequently cause the pineapples to show a stunted growth from which they rarely recover. Usually the second planting even on soils that produced abundant harvests, results in greatly reduced yields.

LACK OF DRAINAGE.

The reduction of the pineapple-producing power of these soils has called for inquiry, both by the farmer and by the Station. Various expedients such as fertilizers, lime, manure, etc., have been tried, and often with indifferent success. Without excluding other possible factors it has been recognized for some time that the fundamental difficulty is associated with inadequate drainage, that under the existing conditions the water-holding power of the soil becomes greatly increased, that percolation and consequently drainage is hindered by the methods employed. In the old fields there are generally isolated plants or small areas that are more thrifty than the surrounding plants. Close examination has shown that the more thrifty plants are found on slight elevations such as a back furrow or ridge made by throwing together two furrows, etc. Upon pulling up the unthrifty plants the roots are often found to be dead, except perhaps one or two small roots near the surface. Sometimes only one root barely beneath the surface of the soil is the only living subaereal part of the plant. The underground part of such plants is frequently undergoing putrefactive decay, and even several days after rains they may be surrounded by a wet soil containing stagnant water.

The pineapple, like all cultivated plants, requires free circulating air around its roots; it demands oxygen just as animal life requires it. Probably nothing is more effective in preventing proper aeration in soils than stagnant water, or a water-logged condition in which the inter-spaces or pores of the soil are more or less completely filled with water. Air is then largely excluded, the necessary oxygen is shut out and conditions unfavorable to plant growth ensue. Under such conditions the soil bacteria can not perform the functions so necessary in the preparation of plant food, and fertilizers can not do their normal duty. Evidently the development of roots near the surface of the soil, above referred to, is an effort by the plant to secure oxygen through its absorptive organs.

The introduction of surface ditches has usually been beneficial, but rarely of itself restores the soil to its original fertility, and not even when used in conjunction with liberal quantities of high-grade commercial fertilizers. It has been suggested that under the influence of a tropical sun, continuous cultivation would bring about an oxidation of the soil organic matter. Humus, as is well known, has the property of making heavy

Issued December 13, 1916.

Hawaii Agricultural Experiment Station
HONOLULU

J. M. WESTGATE, Agronomist in Charge.

PRESS BULLETIN No. 51.

The Spraying of Yellow Pineapple Plants on Manganese Soils with Iron Sulphate Solutions.[1]

By M. O. JOHNSON
Chemist

INTRODUCTION.

The yellowing of pineapples on the black manganese soils of the island of Oahu has been a serious problem to the growers for a number of years. The yellowing of the leaves of the pineapple plant, the stunted red or pink fruits, many of which crack open and decay, and other toxic effects of the manganese soils are familiar to those interested in pineapple culture in the Islands. Previous work by this station has shown that this yellowing is correlated with the presence of abnormally large quantities of manganese in the soil and the characteristic effects of the manganese have been described in previous bulletins of this station.[1]

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[1] NOTE:—This press bulletin is a condensation (in popular form) of a forthcoming publication of this station in which the work accomplished is given in much fuller detail, especially as regards its scientific aspects and its relation to other investigations along similar lines. It has been known for a good many years that soils containing excessive quantities of limestone may cause a chlorosis or yellowing of certain plants grown on them. Treatment with iron salts has been used in some cases of such chlorosis of grape vines and fruit trees in France, England, and elsewhere for a number of years. Gile of the Porto Rico Experiment Station [Bul. No. 11 (1911)] found a chlorosis of pineapples on certain Porto Rican soils containing large quantities of calcium carbonate (limestone) derived from coral sand. No manganese has been reported in these Porto Rican soils. Gile found that iron solutions applied to pineapple leaves suffering from this *lime-induced* chlorosis on these limestone soils resulted in the restoration of the green color but he did not consider this method

From a study of the ash analyses of different kinds of plants, it was found that the plants to which the manganese soil appeared toxic, such as pineapple, corn, pigeon pea, etc., have less iron in their ash when grown on manganiferous soils than when grown on normal soils. Ash of such plants as guavas and weeds growing wild on the manganese soils without apparent ill effects showed no decrease in iron, yielding even more iron than when grown on normal soils. The other elements in the ash showed no such significant variation. It thus appeared that the unhealty growth on the manganese soil was due to lack of iron in the plants and that the plants were suffering from iron starvation in spite of the abnormally large quantities of iron present in the manganese soils. A small amount of

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of treatment economically practicable. The name "chlorosis" is a general term for a diseased or unhealthy condition shown by the loss of the green coloring matter. This chlorosis or yellowing may result from a number of causes such as lack of nutriment, poor drainage, bacterial effects, etc. As such a variety of causes may induce a yellowing of the leaves of a plant, and as the manganese soils of the Hawaiian Islands contain no limestone and so small an amount of lime that they are acid to litmus, it had not previously been thought that lack of iron had any connection with the "*manganese yellows*" of the Hawaiian pineapples, especially as the manganese soils are extremely high in iron, containing from 10 to 30% of iron oxide. The presence of such large quantities of iron in the soil seemed to preclude the idea that the plants could be suffering from a lack of iron in their tissues. The line of attack on this problem as outlined in the present bulletin indicated however that the trouble was due in a large part at least to the difficulty of the plant in obtaining sufficient iron in the presence of abnormally large quantities of manganese. It thus apparently remained for this station to work out a practicable method for combating the *manganese-induced* "yellows" or chlorosis of pineapples. J. M. WESTGATE.

[1] Kelley, W. P., Hawaii Sta. Press Bul. 23 (1908); Kelley, W. P., Hawaii Sta. Bul. 26 (1912); Wilcox, E. V. and Kelley, W. P., Hawaii Sta. Bul. 28 (1912).

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iron is necessary for the development of chlorophyl (the green coloring matter of the plant) and the consequent health and vigor of the plant.

SUMMARY OF EXPERIMENTS IN SUPPLYING IRON TO THE PLANTS.

Experiments in supplying iron salts to the pineapple plants suffering toxic effects on manganese soil have confirmed the conclusions derived from ash analysis, as the yellow plants treated became green in a short time and commenced a vigorous growth. The application of solutions of iron salts to the leaves was the only promising treatment. Addition of acids, of solutions of iron salts, and of solid iron salts to the soil appeared of little value. Ferric chlorid (chlorid of iron) gave more rapid results than sulphate of iron (copperas), but because of the much higher price of the former and its tendency to burn the plants, copperas is preferred. Iron sulphate solutions con-

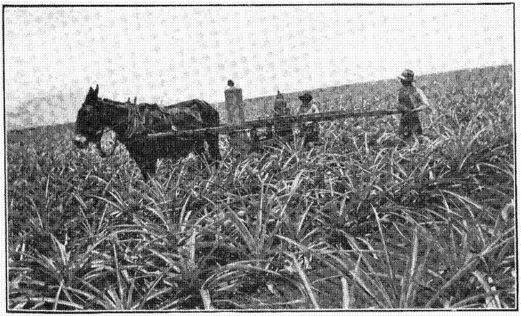

Fig. 1. Front View of Experimental Sprayer.

taining a small amount of acid, such as oil of vitriol (Sulphuric acid), acetic acid, or acid waste pineapple juice, were slightly more effective than iron sulphate alone in restoring the normal green color, but more burning to the plants was noticed. The addition of small quantities of nitrate of soda to the solution of iron sulphate applied to the leaves gave slightly more rapid restoration of the green color. Inasmuch as the after-effects of repeated sprayings with mixtures containing nitrate of soda have not as yet been observed it is too early to advise definitely in regard to its use, especially in view of the known injurious effects of sodium nitrate when applied directly to pineapple soils. Sulphate of ammonia similarly added seemed to have no immediate effect, but some benefit may be expected from the part of the spray that reaches the soil.

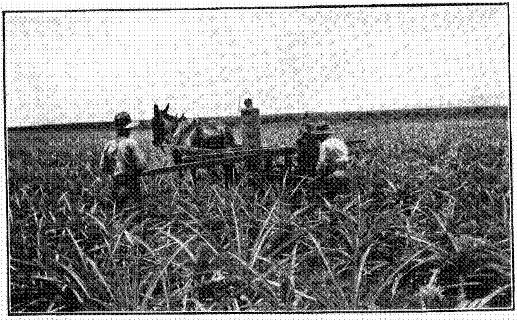

Fig. 2. Rear View of Experimental Sprayer.

From a comparison of solutions of various iron salts, of various strengths of solution, of solutions containing acid, of various numbers of applications, and of various methods of application in the treatment of the yellow plants on manganese soil, the most economical and effective treatment appeared to be three or four applications of an approximately 8 per cent solution of iron sulphate (32 pounds of copperas to 50 gallons of water) sprayed from above.

FIELD EXPERIMENTS.

The cooperative field experiments in spraying extensive areas of yellow plants on manganese soils with copperas solution have been very successful, the plants becoming green and vigorous. The effect on the stunted red fruit was striking, the normal healthy green color developing and very rapid growth taking place.

THE SPRAYER USED.

Figures 1 and 2 show the front and rear views of the experimental sprayer used. This sprayer was designed by Mr. Simes T. Hoyt, of the Hawaiian Pineapple Co., and was built at a low cost by the plantation blacksmith. The sprayer is mounted on a single iron wagon wheel so that turning is easy at the end of the rows. A carbonic acid tank in the rear furnishes pressure sufficient for spraying about 80 acres, according to the method used. Recharging the carbonic acid tank costs $4.00. This tank is connected with a 30-gallon tank in front holding the iron sulphate solution. A gauge on the 30-gallon tank shows the pressure, which is kept at about 30 to 40 pounds when spraying. A pipe leads from this tank to the spray nozzles which cover the two rows on either side of the machine. When the sprayer is drawn at a reasonably fast walk, spraying four rows at once and using 13 gallons of solution to an acre, about 20 acres per day are covered.

SPRAYING COSTS.

Since a preliminary newspaper announcement[1] of the benefits to be derived from spraying with solutions of iron sulphate the plants suffering from "manganese yellows," practically all pineapple plantations on the Islands have experimented with different sprayers using the iron spray. So far success has everywhere been reported. The cost of spraying with all these different sprayers has been considered negligible in comparison with the other expenditures necessary in the raising of pineapples. With the experimental sprayer described above, the cost amounted to approximately 60¢ an acre per spraying. Due to the low cost of spraying, the relative cost of operation of different sprayers need not be compared.

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[1] Pacific Commercial Advertiser, Honolulu, T. H., July 21, 1916.

MAIN FIELD EXPERIMENT.

As the various growers all report success from spraying with iron solution, it is deemed unnecessary to give in this publication all the proofs of the practical value of the treatment. A few details of the main field experiment will be given.

This main experiment was in a large field in Helemanu where the plants were very yellow and were setting the characteristic stunted red fruit. With the exception of the check rows, the part of the field chosen for this experiment was gone over four times with a hand sprinkler containing a solution of 10 pounds of copperas to 50 gallons of water, after which it received three sprayings with the machine described above. Two 300 30-foot rows were left untreated as checks and two more received only a single spraying. The two rows adjoining the unsprayed rows were held for comparison with them.

The effect of the treatment on the yellow plants was quite striking, both the plants and fruit becoming green, the fruit showing especial stimulation. Figure 3 shows the sprayed and unsprayed rows about a month after the treatment applied in April, 1916. A comparison of the fruit on the unsprayed and sprayed rows indicated the value of the treatment. A short summary of the yields on the sprayed and unsprayed rows is given in the following table:

RESULTS OF SPRAYING PINEAPPLES ON HIGHLY MANGANIFEROUS SOILS WITH IRON SULPHATE SOLUTIONS.

	Unsprayed rows.	Rows receiving single spraying.	Rows receiving full iron spray treatment in April.
Plants from which fruit was harvested	108	151	244
Plants bearing fruit too young to harvest	0	5	9
Plants blossoming	3	1	11
Plants starting to bloom	0	0	36
Plants dead	31	0	0
Plants with fruit cracked open and decayed	101	81	0
Plants very yellow with no evidence of blosson	57	62	0
Total	300	300	300
Total weight of fruit harvested .... pounds	310¼	431 15/16	774⅜
Average weight of fruits .... "	2¾	2⅞	3 3/16
Fruits harvested	108	151	244
Fruits classed as "first" or No. 1[1]	39	75	214
Fruits classed as "second" or No. 2[1]	69	76	30
Fruits classed as No. 1 .... per cent.	36.1	49.6	87.7
Weight of No. 1 fruit .... pounds	128 11/16	250 7/16	700 3/16
Weight of No. 2 fruit .... "	181 9/16	181½	74 3/16
Total weight of fruit .... "	310¼	431 15/16	774⅜

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[1] Cannery classification by diameter.

DISCUSSION OF TABLE.

An examination of the table shows the practical value of the iron spray treatment. Full details of this experiment will be given in the larger forthcoming publication of this station.

Figure 4 shows the sprayed and unsprayed rows (June 30, 1916). This view is taken about half way along the rows looking south. On the unsprayed row can be seen the plants classified in the table as (a) bearing decayed fruit, (b) very yellow with no evidences of blossom, and (c) as plants dead. Nearly all the fruits from the unsprayed rows had to be classed as No. 2, because of their small diameter and undesirable shape. Besides this, the very inferior quality of the manganese fruit is well known. The cylindrical development of the fruit observed in the sprayed rows is much desired by the canneries, as this shape causes least waste in sizing for the cans.

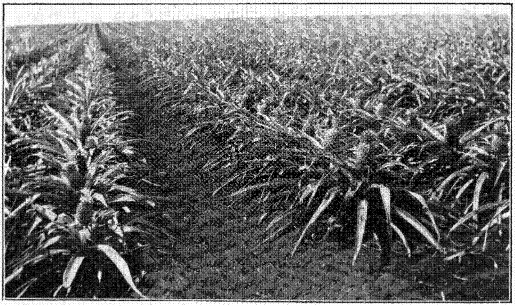

Fig. 3. Main Field Experiment (May 19, 1916). Rows Sprayed in April (on right) vs. Unsprayed Rows (on left).
(Note the diminutive stunted fruits on the left. The photograph fails to show the yellow color of the unsprayed plants.)

Although the rows receiving a single spraying had only a slight greenish tinge, an increase in yield from the single spraying is to be seen from the table.

PRACTICAL ADVICE AS TO THE TREATMENT OF MANGANIFEROUS SOILS.

Although the table demonstrates the practical value of iron spray treatment, even when applied, as in this case, to plants suffering during the greater part of their period of growth from lack of sufficient iron, such late sprayings are, however, not advised. The following is a suggested plan of procedure.

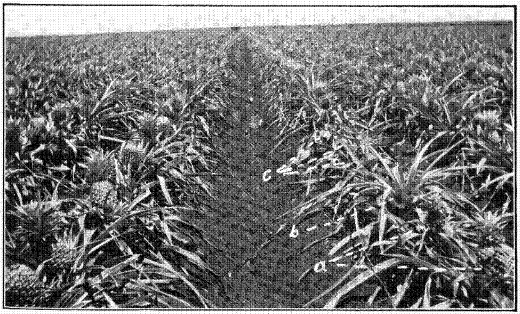

Fig. 4. Main Field Experiment (June 30, 1916). Sprayed Rows (on left (and characteristic effects of manganese soil in unsprayed rows (on right).

Give young planting on manganese soil a single spraying every two to four months, using the color and appearance of the plants as an indication of their need of spraying. Spray the plants when any indications of yellowing or other ill effects appear, the idea being to give the plants sufficient iron to keep them green and healthy. Give plants that are already yellow three or four sprayings at intervals of a week, and spray as necessary to keep them green and healthy.

For the present the use of iron sulphate only in the spraying solution is recommended. The application of small quantities of a fairly strong solution in the form of a fine mist appears most effective and economical. No injurious burning effects have been observed even on young plants.

For this method of application, dissolve about 32 pounds of copperas crystals in 50 gallons of water and apply at the rate of about 13 gallons per acre. For sprayers which take larger quantities of solution to cover an acre, use less copperas to the 50 gallons of water, the idea being to apply about 10 pounds of copperas per acre per spraying.

In the preparation of the manganese soils, when commercial fertilizers are to be used, soluble phosphates and nitrogen as sulphate of ammonia or in organic forms are recommended. Nitrate of soda should not be used. Where stable manure or other humus-forming materials can be applied at a reasonable cost, their use is advised.

The decreasing yield of pineapples with the continuous cropping of non-manganese soils is well known and it is improbable that the manganese soils will continue to give satisfactory crops indefinitely with the iron spray treatment alone. It is probable that the same practices developed for maintaining good yields on the non-manganese soils will also have to be applied to the manganese fields in addition to the iron spray treatment. The management of pineapple soils to maintain the yields has been discussed by Kelley in Press Bulletin No. 29 of this station. The addition of organic matter to the soil and proper provision for suitable drainage at present seem to offer the most promise for the overcoming of the tendency to reduced yields under continuous cropping.

With no method of preparation of the highly manganiferous soils so far tested does the plant seem to absorb sufficient iron, and the iron spray treatment should be applied as soon as any signs of yellowing appear.

Thanks are due and are hereby extended to Mr. J. M. Westgate, director of the station, for heartiest support in this investigation, and to Messrs. J. T. Whitmore, Simes T. Hoyt, and H. Bloomfield Brown, of the Hawaiian Pineapple Company, for their thorough cooperation and help.

soils more porous and thus aiding drainage, and if the humus should become decomposed it would materially affect these lands. Experiments have shown, however, that a slow decomposition of the humus takes place, but that it goes on at such a slow rate as largely to preclude it as the principal factor. Likewise the lack of available plant food, important as it may be, is not at the bottom of the difficulty, for literally hundreds of experiments by the growers and the Station as well, where all sorts of commercial fertilizers in every kind of mixture have been applied in various quantities, have not in themselves restored the land. It is true the nitrifying power of the soil becomes greatly reduced, but the application of commercial forms of nitrogen has not proven effective.

Mechanical analyses of the virgin and cultivated soils show that the ultimate particles that constitute the soil have not been materially altered, which they could not be reasonably supposed to be. The ordinary operations of cultivation are not of such nature as to pulverize and grind to powder the coarser particles of the soil. The mechanical analysis shows, however, that when reduced to its ultimate particles these soils contain a very small percentage of grit or coarse material, and a relatively high percentage of clay and fine silt. They are what would be classified as heavy clay soils, although the so-called clay is of a different nature from true clay in a chemical sense, and while possessing some of the same properties, behaves in other senses vastly different. The word clay in this bulletin is used in a physical sense only, and has reference to the size of the soil particles.

THE CAUSE OF FAILURE.

While the percentages of clay or other constituents are not materially different in the new and old soils, the degree of granulation of the clay is greatly modified. The virgin soil when shaken with a column of water, will soon settle out, leaving practically a clear solution above it, whereas the older cultivated soils when so treated give rise to a turbid solution which will not settle out for weeks.

In the state of nature where good tilth is attained, the particles that constitute the clay content of a soil, particles which when separated are extremely small and will remain in suspension in water almost indefinitely, are collected into aggregates or granules, which granules act as units and impart to the soil properties in every way similar to those brought about by ultimate particles of a much larger size than clay. The bringing about of such conditions in the soil is variously styled grauulation, flocculation, coagulation, etc. It is an important function of cultivation to aid nature in cementing the clay particles into granules, and is accomplished by admitting sunlight and air, and subjecting the soil to different degrees of moisture, carbonic acid, etc.

These soils are frequently cultivated and usually well prepared, but instead of an open granular structure being maintained by this operation, the soil steadily becomes more difficult to till, drainage is hindered, and deflocculation results. The soil is simply puddled. What are the causes of this phenomenon? The principal causes are cultivation, tramping over and otherwise disturbing the soil when it is wet. It is a principle known by farmers for centuries that the cultivation of clay soils when they are wet injures the land and brings about conditions which it may take years to overcome. The intelligent farmer in older agricultural regions will only as a last resort allow the cultivation of his clay soils when they are wet. In the cultivation of wet clay soils the loosely-bound granules become broken up and separated into their component particles, and when once the bonds of union are severed, it is by no means easy to reunite them. We need no better illustration of the effects of tillage on wet soils than is to be found right here among the rice-growers, who deliberately puddle the soil by working it when it is wet in order the better to prevent loss of irrigation water through seepage and drainage.

It is a common practice in the pineapple sections of the islands to cultivate when the soil is practically saturated. At certain times heavy rains thoroughly wet the land and these are often followed by strong winds and a hot sun, which brings about a rapid drying of the surface. Frequently the cultivators are sent into the fields when the surface seems dry enough to cultivate, but the soil two or three inches below the surface is wet almost to saturation. The mere trampling of the soil at such times when continued through a period of years tends to bring about deflocculation of the clay and, therefore, puddle the soil, so that effective drainage is hindered.

Puddled soils hold water tenaciously and under such conditions denitrification instead of nitrification may take place; effective aeration is made impossible and a condition unfavorable for pineapple growth follows. The application of fertilizers to such soils is almost sure to result in disappointment, because the fundamental difficulty is not a lack of plant food. Good tilth, a good mechanical condition in the soil, is just as important as available plant food, and in its absence fertilizers can not perform their normal function and bring about the desired results. In some instances under such conditions fertilizers may even prove injurious. Nitrates in water-logged soils may be reduced to nitrites. Such changes actually take place in some Hawaiian soils, and nitrites are active plant poisons.

Furthermore, soils that contain such large quantities of finely-divided ferric hydrates under the influence of putrefactive decay may be reduced to ferrous carbonate and sulphate, either of which are poisonous to many plants.

It has been shown in other countries and here that the continued use of nitrate of soda on clay soils* also tends to bring about a deflocculation of the soil, and where it has been so used the land remains wet longer after rains. The same condition may arise from the continued use of certain other fertilizers. In the pineapple sections, however, such fertilizers have not come into general use. In fact, no fertilizer has been used in many instances where the soil has assumed a bad condition. It has been found, however, that on some of these soils the application of nitrate of soda tends to aggravate the already existing troubles and, therefore, injures rather than benefits the growth of pineapples.

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* At the Rothamsted Expt. Sta., where nitrate of soda has been in continued use for 60 years, a deflocculation of the soil has resulted. See Jour. Royal Agr. Soc., Vol. 70, 1909, pp. 12-35.

REMEDIES.

The bringing back of these soils into a condition favorable for pineapple growth can not be accomplished in a day and is far easier to prevent than to overcome once it is brought about. With the virgin soils the farmer should by all means strive to prevent such conditions. No heavy clay soils should ever be cultivated when they are wet. If the fields demand attention through the rapid growth of weeds, during rainy seasons, it will be far better to pull out the weeds by hand or cut them off near the surface with hand hoes. The results of cultivating wet clay soils aside from that of checking and destroying grass and weeds, are positively injurious and in fact really hinders one of the very objects of tillage, that is aeration.

Air and sunshine in time will bring about granulation of the soil and by thoroughly stirring it at intervals when fairly dry, nature may be aided in restoring tilth. This should always be accompanied by the best possible drainage that can be provided. When this has been done fertilizers will no doubt prove effective and can be used profitably. Barnyard manure will also aid nature in restoring these soils, by making them more porous and allowing a freer circulation of air, but should be applied some months before the land is to be planted. Lime is also generally recommended for heavy clay soils as a means of making them more friable and improving their tilth, but the application of lime to the pineapple soils of Wahiawa has at least failed to show any advantage to be derived from it. Some of the growers maintain that lime makes the cultivation of the soil more difficult, causes it to remain wet longer after rains and brings about poorer drainage. This subject is now under investigation but it is too soon to draw conclusions. It should be borne in mind, however, that while these are called heavy clay soils, the clay in them is of an altogether different nature from the clay in most countries, and it is not inconceivable that lime will react in a manner likewise different. If lime is to be added as a means of correcting acidity or for other reasons, beach sand is recommended.

It will be far easier to maintain "condition" in these soils under a system of rotation of crops. In fact, some of the Wahiawa soils are almost sure to get into a bad mechanical condition if continuously cultivated in the same crop. It is doubtful whether any crop can be most successfully grown without rotation on soils similar to these. With the vast majority of cultivated crops, it is far better and more permanent to grow them in a system of rotation. Whatever rotation is employed it should include some leguminous crop which is plowed under. This will tend to improve the tilth of the soil and at the same time add nitrogen, an important and deficient element in these soils.

SUMMARY AND CONCLUSIONS.

The continued cultivation of pineapples on the same land has already brought about conditions unfavorable to the growth of the crop. The use of fertilizers, lime and manure have not restored this soil to its original productivity. The mechanical condition of the soil becomes greatly affected and poor drainage results.

While only a slight change has taken place in the humus, the clay has become deflocculated, thus reducing the size of the pores in the soil and effectually hindering drainage. This condition in these soils is brought about and really caused by cultivating the soil when it is wet. In some instances, however, it has been caused by beating rains, accompanied by overflows. In such puddled soils proper aeration is impossible and bad physical, biological and chemical conditions prevail.

The best remedy is that of prevention; these soils should not be cultivated when wet, for damage is sure to result. Sunshine and air aided by thorough tillage when the soil is in proper moisture conditions will assist nature in restoring tilth. The best possible drainage should be provided by introducing ditches at short distances apart. Manure, especially if accompanied with ample aeration, will tend to make the soil more porous and, therefore, aid drainage. And finally, the continued cultivation of the land in pineapples should give way to an intelligent system of rotation.

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Hawaii Agricultural Experiment Station,
HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 30.

Killing Weeds With Arsenite of Soda

BY

E. V. WILCOX,
SPECIAL AGENT IN CHARGE

INTRODUCTION.

Weeds and pests of insect or fungus nature are naturally among the important problems with which the farmer has to contend in all agricultural regions. In controlling these drawbacks to successful production, hand methods were first used but the use of chemicals was early adopted in combating insect and fungus disease. Somewhat later, sprays for the destruction of weeds received attention and chemicals for weed destruction have gradually assumed a greater importance. Many of the facts which are now known regarding the destruction of weeds by means of chemicals were first discovered in connection with spraying for insects and fungus diseases. In order to destroy insects and pathogenic fungi by applications of chemicals to living plants it is necessary to use solutions or mixtures of a strength sufficient to be fatal to the insects and fungi but not injurious to the plants which are to be protected. In the extensive and long-continued spraying experiments which have been carried on in farm practice, it was soon found that certain forms of chemicals used in such operations were more injurious to plants than other forms. Attention, therefore, was required on this point in order to avoid injury to the plants.

In the use of arsenicals for the destruction of insects it is necessary to get a finely divided condition of the arsenical, which is at the same time relatively insoluble. The small undissolved particles then remain on the surface of the leaves until washed off or eaten by insects. Soluble arsenicals are extremely injurious to vegetation and, therefore, have to be avoided in spraying useful plants. There is thus a complete contrast in the ideas aimed at in spraying for insects and in spraying to kill vegetation. Arsenical insecticides must be as insoluble as it is possible to obtain them, while for killing weeds the most soluble form of arsenic is desired.

CHEMICALS USED FOR WEED DESTRUCTION.

In experiments previously carried on at this Station[1] carbon bisulphide was applied to a number of weeds which grow in the garden and fields. This chemical was found to be very effective in the destruction of some of our hardiest weeds, both of herbaceous and shrubby nature. When applied on a large scale, however, and in long-continued operations, there is some danger from the injurious effects of the fumes of carbon bisulphide upon the workmen and the chemical itself is rather expensive. It seemed, therefore, desirable to carry on experiments with other chemicals which could be applied more easily and at less expense. Arsenite of soda has been extensively used on the mainland of the United States, in Australia and elsewhere for the destruction of a variety of weed plants. Stone[2] found arsenite of soda exceedingly effective against herbaceous weeds when used at the rate of one part in 66 parts of water. Gillette[3] in using arsenicals against insects found that the soluble portion of the insecticides exercised a much greater burning effect upon the foliage in the presence of dew and direct sunlight. Kilgore[4]

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[1] Haw. Sta. Press Bul. No. 25.

[2] Mass. Rept. 1908, pt. I, pp. 62-72.

[3] Iowa Sta. Bul. 10, p. 419.

[4] N. C. Sta. Bul. 77b.

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observed that arsenites are more soluble in solutions containing sulphate of copper and sulphate of iron than in water alone. Jones[1] used arsenite of soda on herbaceous weeds and found the effect produced by this chemical to be slow but lasting. The formula used called for one pound sal soda and two pounds of water diluted before using so as to make nine gallons. In Australia the common practice is to buy arsenite of soda already prepared and simply dilute in water at the rate of one pound to five to ten gallons of water. This solution has proven effective in the destruction of the prickly-pear, wild blackberry and various herbaceous and semi-shrubby weeds.

Asenate of soda has in experiments proven even more effective than the arsenite. For example, Stone in the article cited above found that the mixture of arsenate of soda and corrosive sublimate in equal parts caused a very rapid destruction of the foliage and stems of weeds. Likewise, Morgan[2] found that arsenate of soda alone caused a rapid and destructive burning on foliage upon which this chemical was applied, and Jones in the article referred to above reports arsenate of soda when used at the rate of one pound to eight gallons of water, to be rather quicker and more effective in its action than arsenite of soda.

Iron sulphate. In various processes involved in the commercial handling of iron ores, iron sulphate is obtained as a by-product and costs about one cent per pound in most cities on the mainland. This chemical has been widely tested in Wisconsin, Iowa, Maine, South Dakota, Rhode Island and other states, as well as in foreign countries, and upon a large variety of weeds, but chiefly upon wild mustard. For this purpose it has been found particularly effective and has the further advantage of not destroying cereal grains. For this reason it is commonly sprayed over grain fields infested with wild mustard, and when thus used gives excellent results. Iron sulphate has been used in different strengths, but where the herbage is quite tender a 20 per cent solution is the one commonly recommended to kill weeds and not injure cereals. Iron sulphate is readily soluble in water, and no other manipulation is required for the spray than simply to dissolve the chemical in water. At the Station iron sulphate has been used upon spurge, cockle-bur, lantana, oi, pig-weed, Japanese nut-grass and other weeds. When used at the rate of three pounds per gallon of water, iron sulphate killed all these weeds except lantana and Japanese nut-grass. The leaves were destroyed on lantana but the new buds were sent out, showing that the stems were not killed. The portion of Japanese nut-grass above ground soon turned brown and died after being sprayed with iron sulphate, but fresh shoots came up from the under-ground bulbs. This chemical can be used effectively against most weeds except lantana and Japanese nut-grass, and has the advantage of not being poisonous or in any way injurious to the soil.

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[1] Vt. Sta. Rpt. 1901, p. 248.

[2] Agric. Education, 6 (1903) p. 11.

Carbolic Acid. When diluted at the rate of 1 quart in 8 gallons of water, Jones[1] observed little effect on common weeds from spraying with carbolic acid. On the other hand, Voelcker[2] obtained satisfactory results from spraying wild onion with a 5 per cent solution of carbolic acid, and the same chemical proved effective in experiments on miscellaneous weeds at the Massachusetts Experiment Station.

Benzine. This substance has been tested on a small scale in destroying weeds in gardens in various localities. Stone[3] reports that a 50 per cent mixture of equal parts benzine and gasoline in water was effective against the less hardy weeds.

Kerosene. In preparing kerosene mixture as a spray for sucking insects, it is always recommended that care be taken not to leave any of the kerosene uncombined with the soap in the mixture, for the reason that if uncombined the kerosene may burn the foliage. Kerosene has a slight burning effect on the foliage of various trees. It was tried by Wilson[4] as a spray for weeds at the rate of 6½ gallons per square rod. When thus used it was not efficient enough to warrant its application on a commercial scale.

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[1] Vt. Sta. Rept. 1901, p. 248.
[2] Jour. R. Agr. Soc. Eng. 63 (1902) p. 360.
[3] Mass. Rept. 1908, Pt. I, pp. 62-72.
[4] Minn. Sta. Bul. 95.

Salt. The injurious effect of salt upon vegetation is a matter of common knowledge. Plants show some variation in their resisting power to salt, but a maximum salt content is soon reached in the moisture of the soil, after which the plants die or can not thrive. Salt has been applied for killing weeds, either dissolved in water or sprinkled upon the ground about the weeds to be destroyed. Salt is chiefly valuable for this purpose in sidewalks or roadsides where it is not desired to grow cultivated crops after the weeds are destroyed. In such places there is no harm from the presence of large quantities of salt in the soil. As a spray it has been found that salt applied at the rate of 80 barrels is inefficient for the destruction of field weeds. It is, therefore, scarcely to be recommended in the list of commercial weed destroyers in field practice.

Sulphuric acid. On account of its great oxidizing and burning power, sulphuric acid has frequently been thought of as a weed destroyer. When used in a 15 per cent solution in water, Wilson[1] found sulphuric acid to be very efficient for destroying weeds but rather too expensive. Similar results have been obtained in Maine and elsewhere. Sulphuric acid is objectionable on account of the danger connected with its use by ordinary laborers, and its destructive effect on spraying apparatus. At the Station sulphuric acid was tried as a means of destroying guava, but without satisfactory results.

Copper sulphate. Copper, both in the form of sulphate and nitrate, but particularly the former, has been widely used in killing various kinds of weeds, especially wild mustard. The effectiveness of copper sulphate for this purpose has been thoroughly demonstrated, both in Europe and the United States. A 3 to 5 per cent solution is commonly recommended to be applied as a spray. Hitier[2] had excellent results in destroying wild mustard from spraying with a 4 per cent solution of copper sulphate or a 3 per cent solution of copper nitrate. Copper sulphate may be added with a slight advantage to a solution of arsenite of soda, since, when thus used, it increases the solubility and burning effect of the arsenite.

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[1] Minn. Sta. Bul. 95.

[2] Jour. Agr. Prat. 5 (1905) pp. 65-8.

Ammonia. Ammonia has also been used as a spray for the destruction of weeds but cannot be recommended for general use on account of its slight burning power and the disagreeable fumes which annoy the laborers.

Arsenite of soda. This chemical is usually prepared by boiling together common white arsenic and washing soda or sal soda. Theoretically these chemicals combine in such a proportion that if about 1½ pounds of soda be used for each pound of white arsenic, the proper combination will take place to render all of the arsenic soluble by the formation of arsenite of soda. In practice a considerably larger proportion of soda has been used, up to 4 pounds per pound of white arsenic. It seems unnecessary, however, to use more than 2 pounds of soda per pound of white arsenic. In preparing arsenite of soda we have had good results from boiling a mixture of one pound white arsenic and two pounds sal soda per gallon of water for from 15 to 20 minutes. The exact length of time to continue the boiling can not be stated beforehand with any certainty but the boiling should be continued until the solution becomes clear. The clearing of the solution indicates that the proper chemical combination has taken place. In Australia, where arsenite of soda has been widely used for killing weeds, the common practice is to buy the arsenite of soda as such on the market, but in the spraying thus far done in Hawaii with arsenite of soda, it has been prepared by boiling white arsenic and sal soda as just described. The stock solution obtained by boiling together the sal soda and white arsenic is to be diluted before spraying with 15 to 24 parts of water, depending on the hardiness of the weeds to be destroyed.

Arsenate of soda. This chemical is about equally soluble with arsenite and where obtainable on the market at a reasonable price may be substituted for the latter. In experiments with miscellaneous weeds, Jones[1] found arsenate of soda very effective when used at the rate of 1 pound to 8 gallons of water. Similarly in Massachusetts arsenate of soda gave good results as a weed destroyer, either when used alone or when mixed with corrosive sublimate in equal parts.

EXPERIMENTS WITH ARSENITE OF SODA.

Before giving an account of the experiments with arsenite of soda at this Station and elsewhere in Hawaii, it may be well to refer briefly to other experiments with the same chemical. In Australia this spray has been widely used for the destruction of prickly-pear, wild blackberry and other shrubby and herbaceous weeds. For this purpose it has proven so effective as to make a wide field for itself in the programme of weed destruction. Maiden,[2] on the basis of a number of experiments, recommends for destroying prickly-pear a solution of arsenite of soda containing 1 pound to from 5 to 9 gallons of water. In other experiments more concentrated solutions were used, particularly for the destruction of wild blackberry and other shrubby weeds. Likewise in Iowa, North Carolina, Vermont, Massachusetts and elsewhere on the mainland, as well as in Europe, arsenite of soda has been used with good success in destroying miscellaneous herbaceous weeds. In Massachusetts it proved effective when used at the rate of 1 part to 66 parts of water. Kilgore[3] found that when an attempt was made to combine arsenical insecticides containing soluble arsenic with fungicides containing copperas, copper sulphate or iron chloride, the burning effect of the arsenite was considerably increased by the presence of the other mineral salts. In spraying experiments for the destruction of insects Gillette[4] observed that soluble arsenites in arsenical sprays produced a greater burning effect in the presence of dew and direct sunlight. These points are worth considering as indicating the conditions under which applications of arsenite of soda should be made in order to obtain a maximum effect.

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[1] Vt. Sta. Rept. 1901, p. 248.

[2] Agr. Gaz. N. S. W. 9 (1898), p. 984.

[3] N. C. Bul. 77b.

[4] Iowa Sta. Bul. 10, p. 419.

At this Station experiments have been carried on with arsenite of soda in testing the effect of this chemical upon a number of weeds, including oi (*Stachytarpheta dichotoma*), lantana, spurge (*Euphorbia peplus*), pualele or sow thistle, pig-weed, purslane, cockle-bur (*Xanthium strumarium*), glue (*Acacia farnesiana*), dodder, Japanese nut-grass, honohono (*Commelina nudiflora*), crotalaria and other weeds. In these experiments the stock solution, as described above, was dissolved in from 15 to 20 parts of water. The effect of the spray was manifest in most instances within 2 or 3 hours, but on Japanese nut-grass the leaves did not turn brown until the second day. On all of these weeds the leaves and stems ultimately died as a result of a single application.

In spraying alfalfa infested with dodder the alfalfa was killed as well as the dodder. In this respect the results were the same as those obtained with spraying with iron sulphate. The leaves and small stems of lantana were destroyed by a single application, but for the complete destruction of the plant a second, third or even fourth treatment was found necessary. With sow thistle, although apparently destroyed, it seemed to recover rather promptly and grew up again from the base of the plant. Similar results have been had in Nahiku in spraying this plant. Some difficulty is likely to be experienced in destroying honohono on account of the fact that in dense patches it is hard to reach all portions of the plant with the spray and two or three applications may be necessary. Japanese nut-grass, although entirely destroyed above ground by the arsenite of soda spray, promptly grew up again from the underground bulbs without showing any serious diminution of vigor. In previous experiments of the Station it was found possible to destroy this plant with carbon bisulphide, but this chemical is too expensive for use on a large scale. Judging from the experiments which have thus far been made, the best way to destroy this weed economically is to shade it out by using pigeon-peas and allowing them to occupy the ground for a year or more.

In the practical application of arsenite of soda on a large scale in Hawaii, the chief credit is due to Mr. W. A. Anderson, Manager of the Nahiku Rubber Company. In consequence of the satisfactory results which he has obtained, the method has been generally adopted by all of the other rubber companies. More than 500 acres of land covered with miscellaneous shrubby and herbaceous weeds have already been cleaned by means of the spray, and ultimately the whole area now planted to rubber will be treated in this way. Some of the experience of Mr. Anderson is stated as follows in a letter from him:

> "We use it for all troublesome grasses according to the following formula: 2 pounds crystal sal soda, 1 pound arsenic, boiled in 1 gal. water until clear. This is diluted in about 24 gals. of water in the field and applied at the rate, roughly, of about 100 gals. of the diluted mixture per acre, more or less according to the length and thickness of the growth.
>
> "We find this effective for all the grasses we have to deal with, and for the Hitchcock berry and for the general run of weeds, excepting pualele (milkweed), ginger, and wild taro. For best results on honohono a little stronger solution, perhaps one gallon of stock mixture to 20 of water, is necessary. Diluted 1 to 24, it is partially effective with the three exceptions given above, and I feel sure that used slightly stronger, it would dry them up, as it does the grasses and ordinary weeds.
>
> "In a complete list of the plants affected, lantana could not be omitted, as it burns the leaves off, and I have in mind a patch treated over a year ago which has not grown yet. It is unquestionably safe to say lantana can be kept in check with it, the fact having been demonstrated that the growth above ground can be killed, the conclusion would be natural that by keeping at it, the roots in time might be starved out.
>
> "Hilo grass is actually disappearing from our fields that have been plowed, and thereafter treated with the spray. Considerable areas are entirely free from it, and it has been thinned out everywhere."

For several years the Hitchcock berry or thimble berry, and German ivy (*Senecio mikanioides*) have been encroaching on the grass lands of some of the ranches on Hawaii, particularly the Parker Ranch. The method of eradication at first adopted was that of digging out by hand. In this way about $1500 per month was being expended on these weeds and the financial burden seemed an excessively heavy one for the single item of weed eradication. As soon as the experiments with arsenite of soda had been carried far enough to warrant a specific recommendation it was urged that this spray be adopted for the weeds on ranch land. An extensive test was at once begun with results which have justified the general application of arsenite of soda. Not only the Hitchcock berry and German ivy are destroyed by this spray but also the nettle (*Hesperocnide sandwichensis*). These are the very worst weeds on ranch land. The use of arsenite of soda as a spray seems to be a practical solution of the problem of their eradication. Large bushes of Hitchcock berry are destroyed by a single application. At any rate the roots have been found to be dead for a distance of 18 inches from the base of the trunk and, of course, the leaves and the stems were all killed by the same treatment.

The method of application of arsenite of soda on rough ranch land or in rubber plantations is a simple one. The most of these lands do not admit of horse-drawn spraying apparatus on account of the junglelike nature of the weeds and the roughness of the lands. A knapsack spray holding about 5 gallons of solution may be carried on the backs of laborers, who can readily make their way through the bushes and grass, covering the vegetation with the spray as they walk along. One laborer can spray from one to two acres per day, depending upon the height and density of the weeds to be sprayed and the character of the land. The total cost of a single application, including materials and labor, varies from $1.25 to $2.25 per acre. The flowers and tender foliage of all weeds are destroyed by a single application and this effectively prevents the immediate spread of the weeds. As a rule the stems and roots of the weeds are destroyed by the first application. Hilo grass, however, lantana and certain other of the hardy weeds may require two or three applications for their complete destruction. About 100 gallons of the diluted spray is usually sufficient for an acre of ground.

In spraying with arsenite of soda it should be remembered that the effect is produced by contact with the aerial portions of the plant. The spray should be applied in the form of a fine mist so as merely to cover the surface of the leaves and the stems. Care should be exercised not to drench the plants, since no more effect would be thus obtained, and the risk would be run of introducing too much arsenic into the soil.

At Ulupalakua some losses have been experienced in the death of cattle from eating a poisonous passion vine which has gradually spread over a small area of the ranch land. The arsenite of soda is now being used for destruction of this plant and also to kill the air plant (*Bryophyllum calycinum*), a useless weed which covers some of the range and prevents other plants from growing. It is commonly considered that red sage (*Salvia coccinea*) causes abortion in cows and mares. The evidence for this belief is quite conclusive and has come from a number of ranches. The arsenite of soda is now being used on Lanai for the destruction of this weed.

The chemical method for the destruction of weeds as described in this bulletin is capable of a much wider application, particularly for killing weeds along roadways and in waste places where cultivation is at present out of the question. It should, of course, be remembered that the arsenite is poisonous and stock animals should not be allowed to browse upon sprayed vegetation until after sufficient rain has fallen to wash off what may remain on the foliage. As a rule the effect of the spray begins to be manifested within a few hours in the withering and browning in the leaves of sprayed plants. They are thus rendered unpalatable as feed for animals. The spray must remain in contact with the foliage for at least two hours, in order to have the desired effect. In applying arsenite, therefore, a clear day should be chosen, or at least one in which it is not likely to rain soon after the application of the pray.

POSSIBLE DANGER FROM THE USE OF ARSENITE OF SODA.

In addition to the danger of stock becoming poisoned from grazing on sprayed vegetation, it seems desirable to consider the possible injurious effect of arsenic upon the soil and cultivated crops which may be growing in the soil at the time, or which may be subsequently planted in it. This matter has already received some attention, particularly by the Colorado Experiment Station. There is still some difference of opinion as to the possible harmfulness of continued spraying with arsenic. Bishop[1] made analyses of potatoes after the vines had been sprayed with Paris green and found that they contained .0002 per cent of arsenic. Breteau[2] made an examination of wine obtained from grapes picked from vines which had been sprayed with arsenicals and found .003 to .2 mg of arsenic per liter of wine. Comere[3] cultivated algæ in solutions of potasium arsenate. This investigator found that algæ not only grew well in nutritive solutions containing arsenate but that arsenic acid could replace phosphoric acid in such plants. Hyslop[4] found that in cattle which had been sprayed with arsenical solutions, arsenic was present in urine but not in meat or milk. Collins[5] made cultures with barley in which arsenic was added at the rate of 11 pounds per acre normally. The grain of barley grown in the pots contained arsenic to the extent only of 4 oz. per acre and the straw 1¼ oz. per acre. Arsenic has been found in minute quantities in the fruit and in all parts of fruit trees which have been continuously sprayed with arsenic. It is well known that plants readily absorb arsenic from the soil but a considerable variation exists in their sensitiveness to this chemical. In the long-continued litigation between the smelters and cattlemen in Deer Lodge Valley, Montana, an excellent opportunity was had of studying the effect of arsenic upon vegetation and live stock. Unfortunately, too little attention was given in this extensive investigation to the effect of arsenic upon plants when absorbed into their tissues. The arsenic in this case was deposited largely upon the surface of the plants in dust which settled from smelter fumes and which contained arsenic in large quantities. In all cases, however, in which careful analyses were made, arsenic was found to have been absorbed into the substance of grasses.[6]

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[1] Jour. Am. Chem. Soc. 28 (1906), p. 184.
[2] Jour. Pharm. Chim. 28 (1908), p. 156.
[3] Bul. Soc. Bot. France 56 (1909), p. 147.
[4] Natal Agr. Jour. 15 (1910), pp. 693-697.
[5] Jour. Soc. Chem. Ind. 21 (1902), pp. 221-222.

The most extensive study of the effect of the absorption of arsenic upon plants has been carried out by Headden.[1] Many fruit trees, both apple and pear, were observed to be in a sickly condition or dying in the orchards of Colorado which had received arsenical sprays for from 20 to 40 years. An examination of the soil under such trees showed the presence of arsenic in varying quantities, the highest being 138 parts per million. In some cases where sickness or death of the trees was observed the arsenic content of the soil was at least ten times that of normal soils in that locality. The orchardists were found to have been applying for years what must be considered as excessive amounts of arsenic. In some cases as much as 0.9 of a pound per tree. In a period of six years this would amount to 432 pounds per acre or about 108 parts per million in the first foot of soil. The first symptom of poisoning in the orchard trees was a premature yellowing of the leaves. If the application of the arsenicals was repeated the next year the trees died the second year. Serious injuries were also produced in these orchards from the corrosive effect of the arsenic which ran down the trunks of the trees. The bad effects were most noticeable at the collar of the trunk near the surface of the ground.

In view of the somewhat divergent opinions which have thus far been expressed relative to the effect of arsenic upon plants, we may well inquire what may be considered the outlook from the continued use of arsenite of soda as a weed destroyer in Hawaii. The results announced by Headden and referred to above have been called in question by other writers but without substantial evidence to disprove his position. Our experience in Hawaii is of only two years' duration. In a letter from Mr. W. A. Anderson of Nahiku, Maui, the following statement is made on the point under consideration:

"As you know, we have been using the spray for nearly two years now, in quantities, and have not been able yet to observe any injurious effects on the trees. Where it has been applied frequently enough to keep the ground in a measure free from weeds, a marked improvement is noticed in the appearance of the soil, as I suppose might be expected from exposing it to the air."

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[6] Jour. Am. Chem. Soc. 30 (1908), pp. 915-946.

[1] Colo. Sta. Buls. 131 and 157.

In applying the arsenite spray on the rubber plantation of the Pacific Development Company a considerable quantity of the solution was accidentally upset near two rubber trees and the leaves fell from these trees within two days apparently from the poisonous effects of the arsenite. The trees, however, are recovering.

The conditions under which arsenite of soda has been applied in Hawaii differ greatly from those which prevail in apple orchards in Colorado. In the first place we are applying only five pounds of arsenic per acre and to soils which normally contain no arsenic. Then, too, the rainfall in rubber plantations is very high (160 to 200 inches per year). In the spraying experiments in the Colorado apple orchards the most insoluble form of arsenic was used. When washed down into the soil it, therefore, remains for a long time, gradually becoming soluble and being absorbed by the roots of the trees. Arsenite of soda is an extremely soluble form of arsenic. It is not known whether a considerable quantity of the arsenite of soda may subsequently be fixed in the soil by interaction with other chemicals found in the soil. The soils in the rubber plantations, however, are extremely porous and are underlaid with a-a to such an extent that running streams are rare. It is highly probable, therefore, that the most of the arsenite of soda washed into the soil by rains is carried away by the water passing through the soil. It seems very doubtful whether any serious accumulation of arsenic can take place in the soils of the rubber plantations so long as the conditions remain as at present. It can not be questioned, however, that arsenic in excessive quantities in the soil is injurious to nearly all forms of vegetation, and, therefore, some care should be observed in not using unnecessarily large quantities of the arsenical spray. No harmful results have thus far been observed upon rubber or other cultivated plants in Hawaii from arsenicals and it is not likely that harm will result, at least in porous soils such as prevail in rubber plantations, particularly with the very small quantities of arsenic which are being used. The effects of arsenic will be closely observed and if any injury should manifest itself in years to come, the danger may be avoided by adopting for a year or so the harmless but somewhat less effective method of spraying with sulphate of iron.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 31.

Brief Instructions for Farm Butter Makers.

BY

F. A. CLOWES,

SUPERINTENDENT HAWAII SUB-STATIONS

The Territory of Hawaii consumes annually about $150,000 worth of imported butter and oleomargarine. The prices paid range from forty cents to seventy-five cents per pound. Besides this, there is an enormous amount of "Island" butter sold. Housekeepers prefer the island product if it is good, but the supply of *well made* butter is not equal to the demand.

Island butter does not keep well. It is the purpose of this bulletin to give simple rules for producing good flavored butter that will keep well.

FLAVORS ABSORBED FROM OUTSIDE.

Milk and butter are much influenced by odors in the air. If the milking is done in a bad-smelling stable, the milk is almost sure to absorb it. For this reason the place where the milking is done should be kept clean. The milk should be removed from the stable as soon as possible after milking into a sweet, clean place.

FLAVORS PRODUCED WITHIN THE MILK ITSELF.

If milk is kept free from bacteria it will never sour. There are few bacteria in milk as it comes from the cow, but they multiply very rapidly. Dust dropping into the milk from the air carries multitudes of them. When the sun shines through a crack we see myriads of little specks of dust floating in the air. These little air-ships are in dry air at all times, and are constantly rising and falling. Each one carries perhaps a hundred germs. Many of these are good germs, but most of them will give trouble to the butter-maker. Cow hairs are loaded with undesirable germs. When hairs get into the milk, they introduce into the milk countless germs to make trouble for the careful butter-maker. So it is with flies, poorly washed milk buckets and utensils, and dirt of any kind. Many of the bad flavors and other troubles of the butter-makers are caused by bad germs. The careful butter-maker must carefully guard his milk and cream against undesirable germs. Nevertheless in spite of all that can be done, cream will have undesirable germs in it. It is customary therefore, at creameries to pasteurize the cream as soon as it is separated. This can be done by heating the cream to 150° F. or 160° F. and then cooling it down as quickly as possible to the souring temperature, which is usually about 60° to 70° F. Pasteurizing kills nearly all germs.

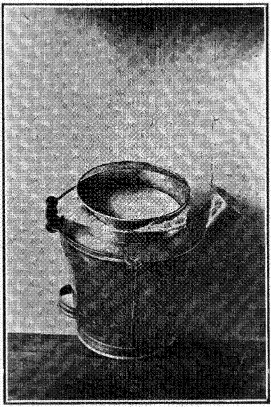
THE RIPENING OF CREAM BY DESIRABLE GERMS.

Now comes the time to take into account the desirable germs. Scientists can show us under the microscope, minute organisms, of a certain species which produce the most desirable flavors in butter.

In large modern creameries, these germs are carefully reared and introduced into the pasteurized cream. This process is too elaborate for the farm butter-maker, but similar methods are used by many farm butter-makers. It is a common practice of good butter-makers to add to the sweet cream 24 or 48 hours before churning, some sour cream or milk or some buttermilk.

EXCHANGE
MICHIGAN STATE College
MAR 22 '40

This "starter"*1 as it is called, must be of a pleasant acid taste, or it will do more harm than good. About one part of starter to ten parts of cream should be used, if the cream is to be soured



The Most Sanitary Style of Milk Bucket

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*1 There are two different classes of starters—the NATURAL, including sour milk or cream, buttermilk, or whey,—and the COMMERCIAL.

The natural ones usually contain several species of bacteria (some good, some bad)—while the commercial starters are divided into "pure cultures" made up from a single individual of a single species, and "mixed cultures" containing different species, but only those whose action is known to be beneficial.

A more varied product is made from the use of the natural starters, while with the commercial as long as they are kept pure—a very uniform article of butter can be secured since these contain only those germs which give to the butter the proper flavor and keeping quality.

The product from use of Commercial starters probably excels that from use of natural ones as much as the latter excels that made in the old-fashioned haphazard way.

Ref.—Wis. Bul. No. 246,—Iowa Bul. No. 103,—Wis. Bul. No. 181.

in 48 hours. When a longer time is to be allowed, less starter will be needed. It is a good plan to get some butter-milk from a neighbor who makes good butter, if a good starter cannot be secured at home. This method would be farther improved if the cream were pasteurized before the starter were added. The only instrument needed for this is a common floating dairy thermometer, which can be bought for about twenty-five cents from any dairy supply house. Simply put the cream as soon as separated or skimmed, upon the stove and heat it up to 150° F. or 160° F. Then cool it to the temperature at which it is to be kept until sour, and add the starter. Of course where the cream from three or four separations is to be mixed together, the starter need be added only once,† but each lot should be pasteurized. By pasteurizing the cream and using a starter, the butter will be found to keep better than if the cream is allowed to sour by chance. The most common complaint against island butter is that it does not keep. The above method will remedy this evil. As a rule it is best to keep the cream at such a temperature that it will be ready for churning in about 48 hours, but where few cows are kept a shorter time is permissable.

SHALLOW PANS.

Cream or milk should not be kept in shallow pans. These pans expose a great amount of milk to the air and this permits it to absorb bad odors, and also gives great opportunity for large numbers of germs to enter the milk. It also allows the top of the cream to dry out and become tough. This tough cream causes white specks and a mottled appearance in the butter.

DEEP CANS.

The cream should be set in deep tin cans, as shown in the illustration. These are easy to clean, easy to handle and expose very little cream to the air. They should be lightly covered, with clean paper, cheese-cloth or a loose fitting cover.

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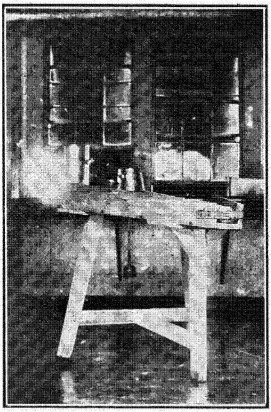
† At the Hilo Boarding School, it was found to be better to add the starter to the **second** of four lots of cream.

WHEN TO CHURN.

Cream is ready to churn when it has a pleasant acid taste and smell, and when it pours like molasses. It requires skill and practice to determine when cream is at its very best state to churn. Even the most skillful and experienced person will make mistakes. On this account it is advisable to use an acid tester to determine the condition of the cream. The outfit necessary for this can be purchased from dairy supply houses for about $5.00, and the use of one of these outfits will do much towards producing a uniform product. Sufficient directions come with the outfit to enable any inexperienced person of intelligence to use it with good results.



A Handy Butter Worker for the Farm

CHURNING.

The barrel churn is the best churn for farm use. When the amount of cream to be handled becomes too bulky for a large sized barrel churn, it will pay to get a combined churn and butter worker, and the latter will pay even with fifteen cows.

TEMPERATURE.

The cream to be churned should be at a temperature of about 55° Fahr. If the buttermaker has a dairy thermometer and uses it, he will soon determine the proper temperature at which he should churn. If the churning temperature is too warm the butter will be soft, and if worked in that condition will become greasy, and it will be hard to get the wash water out. If the cream is too cold the churning may be retarded.

PREPARING THE CHURN.

To prepare the churn, first pour into it a few quarts of boiling water, fasten the lid on loosely so as to permit the steam to escape. Revolve the churn a few times, and then empty out the water. The pressure of the steam will fill all the pores of the churn with water, and the cream will not stick to the churn. The churn must then be cooled off by putting some clean cold water into it. Replace the lid and revolve the churn rapidly three or four times. Empty out the water and the churn is ready to use.

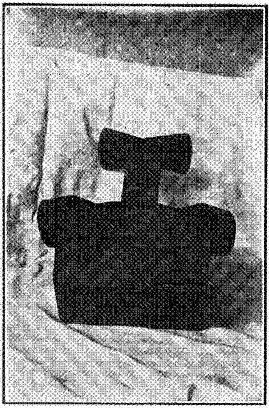
The cream should be strained into the churn through a coarse wire strainer. This will remove lumps of hard curdled cream which cause specks in the butter. If butter color is to be used it should be added at this time, before churning commences.

The churn should be revolved just as rapidly as can be done without having the cream revolve with the churn. It is the splashing which knocks the little globules of fat together so that they are united, consequently the more concussions there are to take place inside the churn per minute, the quicker the butter comes. The wooden plug in the churn should be removed at frequent intervals during the first few minutes of churning so as to permit the gas to escape.

Churning should cease when the butter is gathered in little lumps the size of rice kernels. The buttermilk may then be drawn off through the hole in the bottom of the churn, using the coarse strainer, before mentioned, to catch stray lumps of butter. Let the buttermilk draw off well.

WASHING.

Pour into the churn about as much *very* cold water as there was cream to begin with. Close the churn, and revolve it very fast three or four times. Remove the stopper and let the water drain off.



A Cheap Efficient Butter Printer

SALTING.

Add to the butter about an ounce of salt to the pound of butter. It may be necessary to weigh the butter before salting, but *always* weigh and salt. Remember that salt is cheap, and that it is poor policy to put in less salt than your customers want. The salt should be very fine and should be sifted evenly over the butter, either in the churn, or on the worker.

WORKING.

Butter should be worked till the salt is evenly mixed all through the butter, and till the water does not show in large drops. Remember that customers have no objection to a small amount of water in the butter as long as it does not show. If butter is soft when worked, the water will appear in large drops. Never give a sliding motion to the worker or ladle. A sliding slipping motion tends to give the butter a greasy appearance, which is objectionable. The same thing will happen if the butter is too warm. A wise maker will put his butter away till it is cold, rather than work it soft.

PRINTING.

For the island market butter should be put into pound prints, and be neatly wrapped in parchment paper. Printers can be bought from dairy supply houses similar to the illustration, which are filled by pressing the printer into the mass of butter, and are emptied by merely pressing the plunger. The butter should be put up in attractive packages. It is the outside that sells the article. Rectangular prints are preferable to round.

WASHING DAIRY UTENSILS.

Buckets, cans, etc., should first be washed in warm water and then in water boiling hot. They should be so hot that no wiping is needed to dry them. If they are washed in hot water first, the milk will be cooked on, and they will be hard to clean. Boiling water kills all the germs.

The churn should be wrinsed out with warm water after using. and then with boiling water, after which it should be allowed to drain and air out.

Sunshine is a great germ destroyer. Let the dairy utensils have plenty of sunshine.

BUILDINGS, ETC.

The regulations of the Board of Health about buildings are so explicit that it would be useless to dwell upon that subject in this bulletin.

SHORT RULES.

Germs are the best friends and the worst foes of the butter-maker.

It is one kind of germs that gives good flavor to sour cream.

It is other kinds of germs that make bad flavors in butter.

Do not take chances. Kill the bad germs and grow the good germs. Pasteurize and use a starter.

A small speck of dirt, or a single cow's hair may harbor countless germs. See that your milk is clean.

No dairy utensils except the churn should be made of wood galvanized iron or enamelware. Wooden and galvanized iron utensils are too rough and full of cracks to clean well, and graniteware is good only when new and not chipped. Smooth, heavily tinned buckets and cans with ALL SEAMS SMOOTHLY SOLDERED are the only vessels that can be well cleaned.

A Strong Light Can In Which to Ripen Cream. It is Easy to Clean.

Use a good brush for washing bucket and cans. Never use the dish-cloth. Dish-cloths smear germs all over everywhere. Dish-cloths do not clean corners.

Difficulty in churning is usually due to one or more of the following causes:

1. The cream may be too cold, too thin, or too thick.
2. The churn may have too much cream in it.

3. The cream may have been kept for too long a time.

4. A farrow (or stripper) cow's milk may be causing the trouble.

5. The cows may be getting feed which is too dry.

6. The butter-maker may be incompetent, and should consult an expert butter-maker.

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Hawaii Agricultural Experiment Station,
HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 32.

CULTURAL METHODS FOR CONTROLLING THE COTTON BOLL WORM.

BY
C. K. McCLELLAND, Agronomist
AND
C. A. SAHR, Assistant in Agronomy.

It is a matter of record that cotton culture has been attempted in Hawaii upon several different occasions, but there can be no doubt but what the attempt that has been made in the last few years has been the largest and most systematic of any attempts made. It seems to be that the profitableness of cotton culture is going to depend largely upon the success that is obtained in controlling insect pests. Cut worms, aphis, mealy bugs and others at times cause considerable damage to the cotton plants, but the one pest that does more damage than all others combined is the small boll worm (*Gelechia gossypiella*). In fields where the worm has been undisturbed, as high as 60 to 75 per cent of the bolls have been infested by this boll worm, in which case the cotton that may be picked from the field will not be sufficient to pay any profit on the labor involved in producing the crop.

In Bulletin No. 18 of this Station a detailed description of the insect has been given and from this we take the life history which is as follows:

The eggs are deposited singly upon squares, flowers or leaves—from which in about ten days the larva or worm is hatched. The larva feeds upon the plant for a period of about twenty-three days, after which it pupates and emerges from the pupa as an adult or moth fourteen days later. After a few days the moth will begin egg-laying and lives for several days. The larva is the form that does the damage to the cotton. It may attack the squares or flowers and destroy the vital parts of the flower, in which case the square or bloom falls to the ground. Scores of squares from each plant in our Caravonica field fell to the ground during the month of April as a result of insect attack. The larva also attacks the young bolls in all stages of growth and usually damages the lint and eats out the seed contents and causes a premature opening of the boll.

It has been our observation that Sea Island cotton is more subject to the attack of this worm than Caravonica and Egyptian somewhat less subject, while upland cotton is the least subject of all varieties to their attack. The worm is known to attack other host plants and has been found in Milo (*Thespesia populnea*), may possibly be found in Hau bushes and in India it is said to attack trees which have oil-bearing seeds.

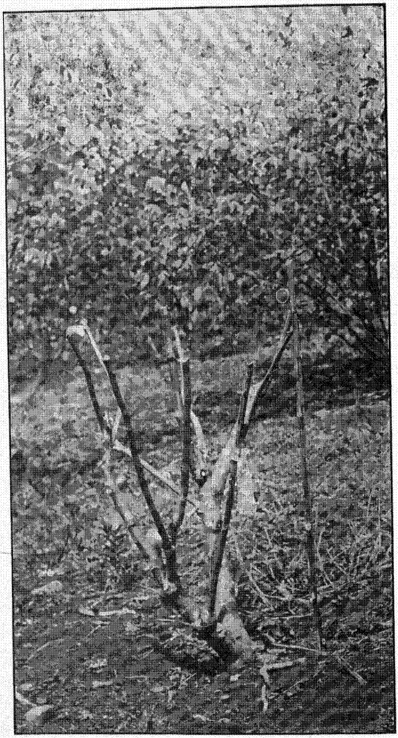
Because of its occurrence in large numbers only upon cotton it will be possible in a measure to control it by cultural methods, and, until an effective parasite is found, we must make the best use possible of such methods. It must be remembered that these additional measures add to the expense of cotton production and so long as effective should be as simple as possible. However, the pruning advocated being necessary for other reasons, only the two others given should be considered extra.

Cultural methods include, first, annual pruning; second, clean culture; third, trapping the mature moths.

ICHIGAN STATE College
MAR 22 '40

PRUNING.

By severely pruning the plants in the fall and burning all branches and bolls immediately, large numbers of the insect in different stages will be destroyed. If no other host plant offers itself most of the insects that survive the fire stand great chance of perishing before new food in the shape of squares, flowers and bolls of cotton will be found in the following spring. It is important that this work should be done in as short a time and in as thorough a manner as possible when once started and that all plants in the vicinity should be pruned. Ornamental plants in yards, or hedges of cotton remaining, or any plants left in the field, serve as breeding places for the insect in which they are carried over for the next crop. This we learned to our sorrow in carrying on a pruning experiment to determine at what time it was best to prune. To secure best results in burning the green branches, a good hot fire should be started with dry material and the work of piling on the brush will be greatly facilitated if the fire is placed in a shallow hole or gulch near the cotton field. In clearing land of guava or other bushes it would be well to leave a part of these in the place where it is intended to burn the cotton prunings.



Cotton Plant Properly Pruned.

Concerning pruning there is much yet to be learned, whether it shall be done early or late, high or low, and for how many years the plant will thrive under such treatment. All that we know is that it is necessary to prune occasionally in order to control the size and shape of the plants and to maintain the quality of the lint. From experiments in 1911 we conclude that with us fall pruning is imperative in order to allow proper development of the plant during the winter months when moisture is plentiful. Plants allowed to bear during this time, then pruned about March first, made plants only about two-thirds as large as those pruned December first. The increase in yield of fall pruned plants was nearly 46 per cent, the average yield per plant being 1.2 pounds and .82 pounds of lint per tree for fall and spring prunings during the second year's growth of the plants.

PERCENTAGE OF BOLL WORM INFESTATION, 1911.

Caravonica 1-2 Acre		Caravonica 1-2 Acre		Sea Island 1 acre—new seeding.	
Date of Picking	Cut back Dec. 5, 1910	Date of Picking.	Cut back Mar. 1, 1911	Date of picking.	
May 31	70.6			Aug. 22*	3.9
June 9	49.5	Jan. 18	19.	" 29	7.9
" 17	26.	" 30	16.1	" 29	8.0
" 24	39.9	Feb. 8	23.6	Sept. 2	21.3
July 5	14.9	" 26	19.5	" 5	23.
" 12	9.8			" 14†	3.9
" 20	11.1			" 18	12.
" 26	7.3			" 20	16.
Aug. 2	9.5			" 20	12.4
" 11	3.1	Aug. 11	3.5	Oct. 7	15.2
" 17	4.2	" 17	3.5	" 12§	6.9
" 26	9.2	" 26	3.7	" 16	13.6
" 31	5.0	Sept. 1	3.8	" 18	13.5
Sept. 8	6.	" 9	2.6	" 26	17.7
" 16	2.9	" 17	2.1	Nov. 1	20.9
" 22	2.	" 23	4.9		
" 28	5.1	" 30	2.7		
Oct. 10	4.3	Oct. 10	1.7		
" 20	5.	" 20	6.5		

* First Picking. † Second. § Third.

From this it will be seen that fall pruning is unquestionably preferable. We have no conclusive ideas as to whether to prune high or low, the high pruning in some cases excelling while in other cases the low pruned plants gave the better yields. One theory given is to prune very low at first and at each succeeding season prune a few inches higher so as always to cut on new growth. After several such treatments it may become necessary to prune low again. Another plan is to cut high and low alternately. However, the form of the individual plant and the conditions under which it is grown, rather than any book rule, will determine the treatment which that particular plant should have. In 1911 the yield from all high pruned plots (four feet high) slightly exceeded that from low pruned plots pruned two feet high. These results were from Caravonica cotton.

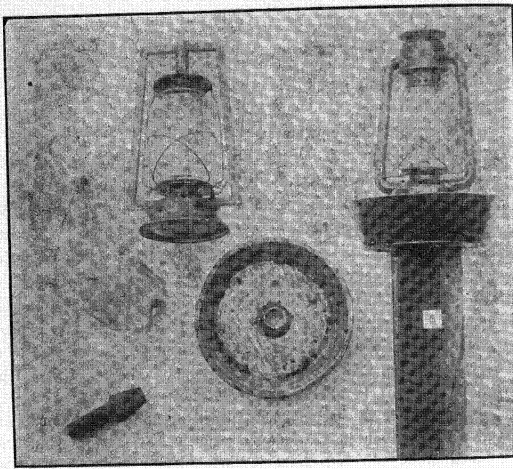
With Sea Island cotton our experience has been that growth starts low even upon high pruned plants so that low pruning becomes necessary. To control the size and shape of the plants the pruning of Caravonica becomes more necessary than for other varieties because of its rank growth, but in order to control the boll worm the pruning of all varieties becomes necessary.

CLEAN CULTURE.

This consists in picking up and burning fallen squares when known to contain the boll worm and, secondly, when picking the cotton the pickers should carry an extra sack in which the infested bolls should be put and carried to the side of the field and later burned. This part of the fight against the boll worm is in many cases very difficult to carry on since the laborers in the field look upon it as just so much extra and unnecessary work, but if any headway is to be made against the boll worm or if any profit from the crop is expected some means should be taken to get this work done by the cotton pickers. At the Station we have also fumigated the seed cotton at the gin house with hydrocyanic acid gas but some of the worms seem to have survived this treatment.

TRAPPING THE MATURE MOTHS.

The moths fly by night and many may be caught by traps. The junior author of this bulletin has improvised a simple device which is herewith illustrated and described. A post is set in the ground, the post being of sufficient height to hold a lantern above the plants so that the light may be seen for some distance. A hole 1 1-2x6 inches is previously bored in the top of the post. Into this a wooden pin (3), shaped as shown in the cut, is fitted. The top of the pin is so shaped as to receive a pan (4) which may be made similar to an ordinary cake tin 2 or 3 inches deep by 12 or 14 inches in diameter. When in position the pan contains water with a coat of kerosene oil. After the pan is placed over the pin a square piece of sheet iron (2) is screwed to the pin to support the lantern. This square sheet of iron should have sides of length equal to diameter of the base of lantern, and should have three corners turned up and with a pin through the fourth to hold the lantern securely. A lantern with larger sized globe (1) is preferable since smaller globes get hot and then break should there come a dash of rain. The trap as put together and set up in the field is shown in the cut (5). The moths fly towards this light and many of them fall into the pan and are destroyed. Many more will be caught upon still nights than upon windy nights. Where winds are prevalent, place trap toward the leeward side of the field and where winds are not prevalent, traps can be placed at equal intervals from each other or in the center of small fields. Two, three or even one such trap per acre will give good results. When one considers the great egg-laying capacity of a single moth it is hard to overestimate the value of capturing 10 to 50 or more moths a night, possibly per acre, if they are plentiful. By pruning partly in December and partly in March we commenced the picking season of 1911 with 70 per cent of bolls infested as shown in the accompanying table, and then by fighting the insect according to the methods given above we succeeded in controlling the situation somewhat and in reducing the percentage of infestation as also shown in the table.



Lantern Trap and Its Parts

Of course the percent of infested bolls in the early pickings is larger than the percent of the total number of bolls, since the worm caused so many of the bolls to open prematurely. The table also shows the greater liability to attack of the Sea Island variety. During the season of 1912 we aim to get the benefit of the annual pruning as described by doing the work all at one time; in which case we hope to have an easier fight than in 1911; yet because of more or less ornamental cotton and milo in Honolulu we can hardly hope to start clean. Upon one large planting where the pruning and burning was well done in 1910,—we are informed that the infestation in the spring of 1911 was very light; but, because of the difficulty to get the pickers to collect infested bolls, the percentage of infestation greatly increased during the season. This shows what can be accomplished by employing the first named method and we have demonstrated the value of the second and third. Other host plants than cotton must always be kept in mind and cut down and burned; then if the grower works faithfully along the lines mentioned above he may hope for some returns for his labors.

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Hawaii Agricultural Experiment Station,
HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 33

A STUDY OF HUMUS IN HAWAIIAN SOILS.

BY
W. P. KELLEY,
AND
WILLIAM McGEORGE.

THE DETERMINATION OF HUMUS.

INTRODUCTION.

During recent years considerable attention has been given to a study of methods for the determination of the ammonia-soluble organic matter in soils. In these investigations some modification of the method originally proposed by Grandeau has usually been employed. In practically all the methods now used the soil is treated with a 4 per cent solution of ammonia after removing the calcium and magnesium by the preliminary extraction with dilute hydrochloric acid, the solution thus obtained being considered the humus solution. In this paper the term "humus" is used to signify the organic matter of soils soluble in a 4 per cent solution of ammonia after removing the calcium and magnesium with dilute hydrochloric acid.

The Hilgard method[1] is a slight modification of the original method as proposed by Grandeau and consists in the preliminary treatment of the soil with a 1 per cent solution of hydrochloric acid on a funnel, after which the soil is extracted with a 4 per cent solution of ammonia until the extract is colorless. During this process the surface of the soil is protected from puddling by a disc of filter paper. The filtrate is then evaporated to dryness and incinerated, the loss upon ignition being expressed as humus.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 38, p. 80.

The method of Huston and McBride[1] consists in shaking 10 grams of soil for a definite length of time with a definite volume of 4 per cent solution of ammonia, after the preliminary extraction with dilute hydrochloric acid. The solution, upon standing 12 hours, is filtered, and an aliquot evaporated to dryness and incinerated as in the Hilgard method. This method, with slight modifications, has been adopted by the Association of Official Agricultural Chemists and will be hereafter referred to as the official method.

For some time it has been recognized that the official method frequently gives abnormally high results, and as has been shown by a number of investigations, this is due to the fact that the clay becoming deflocculated by ammonia can not then be removed by ordinary filtration, and upon evaporating to dryness the solution thus obtained, the clay still contains water of hydration which can not be completely driven off at temperatures below the point of decomposition of the organic matter. Upon incineration, however, this combined water is driven off along with the organic matter, thus giving too high results. Various methods for separating the clay from the humus have been proposed. Cameron and Breazeale[2] used a Pasteur-Chamberland filter; Peter and Averitt[3] deducted from the humus 10 per cent of the humus ash; Mooers and Hampton[4] coagulated the clay by repeated evaporation on a water bath; Stoddart[5] coagulated the clay by use of ammonium sulphate after which he precipitated the humus with hydrochloric acid; Fraps and Hamner[6] used a solution of potassium chlorid to coagulate the clay; Rather[7] attempted to make the separation by means of electro-

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 38, p. 80.
[2] Jour. Amer. Chem. Soc., 26 (1904), p. 29.
[3] Kentucky Sta. Bul. 126, p. 122.
[4] Jour. Amer. Chem. Soc., 30 (1908), p. 805.
[5] Jour. Indus. and Engin. Chem., 1 (1909), p. 72.
[6] Texas Sta. Bul. 129.
[7] Texas Sta. Bul. 139.

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lysis and found that a change in the composition of both the organic and inorganic constituents took place. In addition, he proposed a new method, which consists in coagulating the clay by the use of ammonium carbonate, a salt which is volatile below 100° C. This method has been studied recently by the associate referee on soils for the Association of Official Agricultural Chemists. Recently Wells, Stevenson, and Coover[1] made use of a centrifuge in separating the humus from the clay.

A number of investigations of these methods have been made during recent years, and while practically all are agreed that the official method is unreliable, conflicting reports as to the reliability of other methods have been issued. In a critical study of this question, Alway, Files, and Pinckney[2] compared the Hilgard, official, Cameron-Breazeale, and Mooers-Hampton methods with twelve different soils from Nebraska and concluded from their experiments that the official method is wholly unreliable, while the methods of Hilgard, Mooers-Hampton, and Cameron-Breazeale (when slightly modified) are accurate.

EXPERIMENTAL.

In connection with soil studies in this laboratory, considerable time has been devoted to the determination of the so-called humus in Hawaiian soils and it has been recognized for some time that the results obtained by the use of the official method are unreliable. The soils under investigation were taken from the upper lands of the islands, and while extremely variable, frequently contain a very high percentage of clay. In addition, the clay exists in a state of very fine division. It is a common occurence to find soils, the clay content of which will remain in suspension indefinitely when shaken with distilled water. This study led to an investigation of the methods previously employed in humus determinations.

The soils used in this investigation represent a wide range in composition and properties. The humus, as will be shown varies from 2.64 per cent to 18.27 per cent and the mechanical analyses show a varied physical structure. Since the chief difficulty in humus determinations is associated with the clay, the mechanical composition of the soil used is of some interest.

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[1] Iowa Sta. Bul. 124.
[2] Nebraska Sta. Bul. 115.

The following table gives the results of mechanical analysis of the soils.[1]

Mechanical analysis of soils used in experiments.

	SOIL NUMBERS.										
	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
	Per Cent.	*Per Cent*	*Per Cent*	*Per Cent.*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Organic & Combined water...	44.60	25.83	14.32	13.65	15.80	15.55	13.06	14.67	17.58	16.17	15.55
Fine Gravel......	5.94	1.64	.09	.12	.86	.41	.14	0.29	.06	.09	.96
Coarse Sand......	26.72		.43	.43	.73	1.65	.50	0.91	.26	.42	
Fine Sand	8.65	38.03	1.62	2.11	2.35	1.65	1.33	1.12	.81	2.36	13.58
Silt...........	4.07	16.22	3.37	3.06	9.28	6.72	6.23	7.38	5.60	6.44	6.25
Fine Silt...........	5.09	19 99	27.19	26.32	32.69	18.45	28.88	18.87	22.70	29.07	13.35
Clay..................	5.78	2.05	52.30	55.05	38.60	57.80	47.45	57.80	56.72	44.54	51.26

From the above analysis it will be seen that some of these soils contain very high percentages of clay and fine silt, both of which will remain in suspension for some time. A pronounced characteristic of Hawaiian soils is a very high content of iron, which usually imparts to the soil a red color. In connection with humus determinations, it is important to know not only the amounts of clay in the soil, but something regarding its properties, for, as will be shown presently, clay is a sort of generic term when applied to soils, and usually has reference to the size of the particles and does not imply definiteness regarding their composition and properties. From analyses made in this laboratory, we consider the clay in Hawaiian soils as a mixture of several substances, some of which, perhaps, rarely occur in soils, but which have a decided bearing on the applicability of methods for the determination of humus.

In all humus determinations reported in this bulletin, except as otherwise stated, the solutions were made according to the official method, and when the entire determination was completed by the use of this method the results obtained were as follows:

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[1] Analyses made by the method as outlined by Hall. The Soil. London, 1908, 2. ed., p. 51.

Determinations made by official method showing abnormally high humus ash.

	SOIL NUMBERS.							
	97.	98.	99.	100.	101.	102.	103.	104.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Humus	4.30	5.94	5.12	6.38	4.64	4.34	6.31	3.54
Humus Ash	13.25	20.92	10.54	33.20	15.18	13.15	25.42	7.67

The above data were considered unreliable for two reasons: (1) the percentages of humus are considerably higher than the general properties of these soils would indicate; and (2) the humus ash is many times higher than the humus could possibly contain as mineral matter chemically combined with it. In addition, the humus ash in each instance was found to be red in color and similar in appearance to the clay in these soils. From these results it is at once apparent that the official method is likely to be inaccurate when applied to such soils.

This investigation has led to the study of a number of the most important methods previously used in the determination of humus, and from this study it seems that under certain circumstances a number of these methods will give reliable results. A partial explanation of the disagreement among the several publications dealing with this subject is probably found in the fact that the soils studied were very different in composition and properties. If this assumption be true, it then becomes a matter of both practical and theoretical importance to know the properties of the soil at hand, and if possible, find a method that is universally applicable.

Among the methods used in these investigations are those of Hilgard, Mooers and Hampton, Cameron and Breazeale, and Rather. Since the chief difficulty to be overcome in humus determinations is that of removing the clay, the humus ash has been determined in each instance. The followiing table shows the results as obtained by the use of the several methods:

Comparison of several methods in present use.

HUMUS.

Method.	Soil numbers.										
	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Official	....	....	4.30	5.94	5.12	6.38	4.64	4.34	6.31	3.54	....
Hilgard	15.63	5.26	2.43	2.61	3.68	....	2.95	2.71	....	....	....
Mooers-Hampton	18.74	5.32	2.68	2.70	3.17	2.32	3.72	3.20	3.72	2.68	3.81
Cameron-Breazeale.	12.30	3·98	2.34	2.38	2.91	2.24	2.85	2.24	2.94	2.36	2.29
Rather	20.75	6.49	4.32	4.15	5.01	6.03	5.64	4.38	5.95	4.81	8.24

HUMUS ASH.

Method.	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
Official	....	....	13.25	20.92	10.54	33.20	15.18	13.15	25.42	7.67	....
Hilgard	5.44	1.85	2.46	2.56	2.00	....	4.28	1.82	....	....	....
Mooers-Hampton	6.33	1.33	.60	.84	.65	.41	1.52	1.70	.98	1.17	.44
Cameron-Breazeale.	1.09	1.81	.28	.74	.33	.33	.31	.30	.57	.23	.46
Rather	7.71	2.51	12.94	11.43	10.40	25.69	17.61	10.28	20.49	12.74	32.69

From these results, it is evident that there is a wide range of variation in the percentage of both the humus and humus ash when determined with the various methods, and that a strict concordance does not exist between the results obtained by any two methods. It is true the results obtained by the use of the Hilgard, Mooers-Hampton, and Cameron-Breazeale methods are in fair agreement in certain instances, but on the whole they are too discordant to permit their indiscriminate use. By reference to the humus ash it will be seen that none of these methods save that of Cameron-Breazeale effected a complete removal of the clay in every instance. The Rather method, in most instances, brought about no coagulation of the clay whatever, and therefore, in its original form, can not be relied upon with these soils. By the use of the method of Mooers-Hampton it was found to be necessary to evaporate the humus solutions to dryness, in some instances as many as six times, allowing the residue to bake at the temperature of boiling water for some hours after becoming dry, and even then a partial deflocculation of the clay upon complete resolution in ammonia was unavoidable. In the main, however, this method can be manipulated so as to remove the clay, at least to the point where it is of small importance. The time required, however, together with the fact that the evaporatations have to be made in an atmosphere free from acid fumes, makes the method tedious and impracticable. There is evidence, as will be shown later, that a partial oxidation of the humus also takes place.

The method of Cameron and Breazeale, while originally not proposed as a quantitative method, has been studied by a number of chemists, the results of which show it to be an effective means of removing the clay, but one that is likely to bring about a change in the concentration of organic constituents. The apparatus previously employed makes use of increased pressure supplied by means of compressed air and the solution is forced through a Pasteur-Chamberland tube from an annular space connected with a compression chamber, and is collected from the tubular part of the filter which projects from a close fitting joint below. When solutions are made to volume previous to passing through the filter, and an aliquot taken after passage, considerable difference in the concentration is likely to be observed. Variation in the pressure, as well as different tubes, affect solutions unequally. The effect of the tubes is due to two causes: first, the clay filter has the property of absorbing substances from solutions, especially organic compounds; second, the clay may act as a semipermeable membrane, thus permitting some substances in solution to pass through unchanged, while the concentration of still others is modified.

The humus solution is a complex mixture and, as will be pointed out later, varies greatly from soil to soil so that it seems unlikely that a factor could be found that would compensate for the changes produced in the ordinary passage through a clay filter. The effects produced by the clay filter on the humus solution appear to be largely in the nature of absorption and upon passing the solution through for some time an equilibrium is established between the solution and the filter, and no further change occurs. Some humus solutions, of about 500 c. c. vol., were passed through such a filter, an aliquot of 75 cubic centimeters removed, and the remaining volume again passed through the filter. This process being repeated several times and aliquots removed after such passage as above. These aliquots were evaporated to dryness and incinerated and the results are recorded in the following table:

Effect of repeated filtration through clay filter:

HUMUS.

Soil samples.........	Number of successive filtrations						
	1.	2.	3.	4.	5.	6.	Amounts present in original solutions..............
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
101	1.97	2.06	1.99	2.20	....	....	3.61
102	2.28	1.80	2.20	2.10	2.02	2.02	3.37
103	2.40	2.58	2.32	2.34	2.40	2.52	4.74
104	2.24	2.28	2.60	....	....	....	3.22

HUMUS ASH.

101	0.07	0.06	0.10	0.06	....	....	.78
102	.34	.30	.54	.28	0.20	0.32	.70
103	.18	.36	.46	.30	.32	.36	1.12
104	.78	.72	.36	....	....	....	.76

From these data it is apparent that a pronounced change in the concentration took place during the first passage, whereas successive filtrations produced little further effects.

For example, sample No. 102, whose actual humus content was 3.37% (determined by Mod. Clay Filter method) on passing through the clay filter according to the [1]Cameron and Breazeale method was found to be only 2.28%, or a loss of 1.09%. On repassing this filtrate through the same filter and taking aliquots after each passage there was practically no more absorption of organic matter after the first filtration. This fact indicates the possibility of a state of equilibrium between the filter and humus extract.

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[1] Loc. cit.

Alway[1] and his associates overcame the difficulties attending the use of the clay filter by passing a definite portion of the solution through the filter then forcing through a 4 per cent. solution of ammonia until the filtrate contained no organic matter. The solution and washings thus obtained were combined and made to volume and aliquots evaporated to dryness for the determination of humus. In this study these investigators found this modification of the clay filter method reliable and accurate, but they state that it is too tedious to be of practical value.

A MODIFIED CLAY METHOD.

From the failure to effectively remove the clay by any other means than by the use of the porous clay filter, attention was directed toward overcoming the difficulties attending its use. As a result a slight modification of the method of Alway and others has been found to be both effective and practical, and with which it is, we believe, possible to secure accurate results with any soil. The essential feature of the method consists in passing a definite aliquot of the humus solution through the filter, then forcing through ammonia until the solution contains no organic matter, as was done by Alway and others.

The difficulties of this method have been overcome as follows: The solution is drawn through the filter in the reverse direction from that ordinarily employed. Instead of using the compression chamber, an ordinary suction pump was employed. The tube of glazed porcelain, attached to the lower end of an eight-inch Pasteur-Chamberland tube, was broken off so as to leave this end of the tube open; then the tube was inserted into the upper opening of a bell jar, such as is used for filtering with suction, in a manner similar to that employed in the use of a Gooch. A large part of the tube was allowed to extend into the filtering jar and the connection is made air-tight by means of a short piece of Gooch tubing or a rubber stopper (fig. 1.) It was also found desirable to coat the upper portion of the tube with paraffin so as to prevent the passage of the solution except in the lower half of the filter tube, otherwise the solution will pass down the side of the bell jar.

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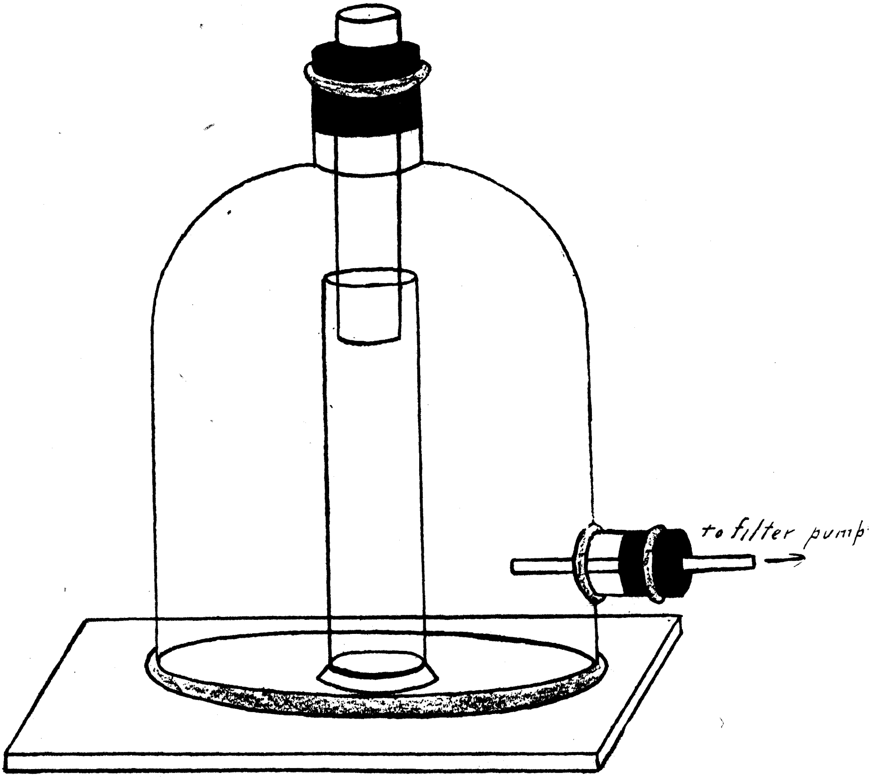
[1] Loc. cit.

FIG I.

Apparatus used in modified Clay Filter Method.



A 50 cubic centimeters aliquot of humus solution,[1] which represents 1 gram of soil, is drawn through the tube by means of reduced pressure, the filtrate being collected in a short cylinder. After the entire aliquot is drawn through, a 4 per cent solution of ammonia is then passed through so long as it shows any color. Usually about 200 cubic centimeters is required. In no instance have we found it necessary to use more than 250 cubic centimeters. The filtrate and washings are then evaporated to dryness and the determinations completed as usual.

Some difficulty was experienced in completely removing the clay in certain soils. There was found to be considerable difference in different tubes in this respect. Some filters will remove all clay, while others seem to allow a small amount of the most finely divided clay t opass through. After each filtration the tube should be washed out. A test-tube brush was found to be serviceable in removing the clay from the inner walls of the filter tube.

The time required to complete a filtration was found to be about 3½ hours, and by arranging a number of filtering jars in a series an ordinary Richardson pump will provide suction for at least three filters, and with close-fitting connections it is probably possible to operate one-half dozen filters with one pump. In any event, at least one-half dozen solutions can be filtered in one day by this apparatus. No attention is required further than an occasional moment for pouring in solutions and the entire process can be carried out along with other work without interruption.

For the sake of comparison, the results obtained by the official, Hilgard, Mooers-Hampton, Cameron-Breazeale, Rather, and modified clay filter methods are submitted in the following table:

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[1] The preliminary extractions with hydrochloric acid were made by digesting 10 grams of soil in 200 cubic centimeters of fifth normal hydrochloric acid at ordinary laboratory temperature for 5 hours, filtering and washing free from acid with distilled water, as outlined by Fraps in his directions for co-operative study of humus determination for the Association of Official Agricultural Chemists, May, 1911.

Comparison of several methods with the modified clay filter method.

HUMUS.

Method.	Soil numbers.										
	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Official	....	....	4.30	5.94	5.12	6.38	4.64	4.34	6.31	3.54	....
Hilgard	15.63	5.26	2.43	2.61	3.68	....	2.95	2.71	....	....	....
Mooers-Hampton	18.74	5.32	2.68	2.70	3.17	2.32	3.72	3.20	3.72	2.68	3.84
Cameron-Breazeale	12.30	3.98	2.34	2.38	2.91	2.24	2.85	2.24	2.94	2.36	2.29
Rather	20.75	6.49	4.32	4.15	5.01	6.03	5.64	4.38	5.95	4.81	8.24
Modified Clay filter	18.27	5.75	2.64	2.81	3.84	3.48	3.61	3.37	4.74	3.22	3.31

HUMUS ASH.

Official	....	....	13.25	20.92	10.54	33.20	15.18	13.15	25.42	7.67	....
Hilgard	5.44	1.85	2.46	2.56	2.00	....	4.28	1.82	....	....	....
Mooers-Hampton	6.33	1.33	.60	.84	.65	.41	1.52	1.70	.98	1.17	0.44
Cameron-Breazeale	1.09	1.81	.28	.74	.33	.33	.31	.30	.57	.23	.46
Rather	7.71	2.51	12.94	11.43	10.40	25.69	17.61	10.28	20.49	12.74	32.69
Modified Clay filter	2.14	2.19	.54	.75	.57	.64	.78	.70	1.12	.76	.99

From these data it is obvious that the modified clay filter method gives results higher than those obtained in any other method, except the official and Rather methods, neither of which can be relied on with Hawaiian soils. In the Hilgard method a cloudy extract continued to run through the filter paper in some instances so that it was impossible to determine by the color when the extraction was complete. Incomplete extractions, therefore, probably account for the low results obtained by this method. By the use of the method of Mooers-Hampton it was found to be extremely difficult to redissolve all the humus without at the same time deflocculating the clay. In some instances a partial oxidation of humus may have taken place. The Cameron-Breazeale method was also found to be unreliable. By any of the previously used methods it was extremely difficult to obtain concordant results with the same soil, while with the modified clay filter method concordant results from separate solutions can easily be obtained, and if the method is used with care, it will give reliable results. The following table shows the agreement in duplicate determinations as obtained by this method, using different solutions in each instance:

Duplicate determinations by modified clay filter method.

HUMUS.

Method.	Soil numbers.										
	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per. Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Modified Clay filter method.........	18.23	5.76	2.61	2.77	3.87	3.41	3.58	3.33	4.82	3.21	3.30
Do	18.31	5.73	2.60	2.85	3.81	3.55	3.64	3.41	4.67	3.23	3.31

HUMUS ASH.

Modified Clay filter method..	2.38	2.22	0.57	.53	0.60	0.55	0.84	0.73	1.10	0.79	0.96
Do	1.89	2.15	.50	.97	.57	.74	.72	.68	1.13	.74	1.03

In co-operation with the Association of Official Agricultural Chemists it was found that the clay in some Texan soils can be readily coagulated by the use of ammonium carbonate. In one instance the clay in a humus solution, which gave an ash of 34.59 per cent by the official method, was completely coagulated by the use of 0.5 gram of ammonium carbonate per 100 cubic centimeters, so that the humus ash in the resulting solution was 0.14 per cent. The use of similar amounts of ammonium carbonate in the humus solutions from some Hawaiian soils effected no coagulation of clay whatever. In certain of the soils, however, it was found possible to partially remove the clay with this amount of ammonium carbonate and this behavior suggested the use of still larger quantities of ammonium carbonate. After a number of trials, it was found that ammonium carbonate at the rate of 4 grams per 100 cubic centimeters, upon standing, effected a complete coagulation of the clay in all the soils examined, except Nos. 69 and 99. The results obtained by the use of the modified clay filter method, Rather method, and Rather modified method, using 4 grams ammonium carbonate to 100 cubic centimeters, are submitted in the following table:

Comparison of Different amounts of ammonium carbonate with modified clay filter method.

HUMUS.

Method	Soil numbers.										
	69.	74.	97.	98.	99.	100.	101.	102.	103.	104.	108.
	Per Cent.	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*	*Per Cent.*
Rather	20.75	6.49	4.32	4.15	5.01	6.03	5.64	4,38	5.95	4.81	8.24
Rather modified	19.34	4.90	2.42	2.41	3.44	3.16	3.37	3.25	3.77	3.20	3.11
Modified clay filter	18.27	5.75	2.64	2.81	3.84	3.48	3.61	3.37	4.74	3.22	3.31

HUMUS ASH.

Rather	7.71	2.51	12.94	11.43	10.40	25.69	17.61	10.28	20.49	12.74	32.69
Rather modified	6.26	1.84	.19	.18	2.11	.13	.81	.10	.24	.18	.13
Modified clay filter	2.14	2.19	.54	.75	.57	.64	.78	.70	1.12	.76	.99

From these data it is evident that by the use of sufficiently large amounts of ammonium carbonate a complete coagulation of clay was brought about in most instances, but by comparing the percentages of humus obtained with those from the use of the modified clay filter method, it appears that a partial precipitation of the humus also took place, and in all the samples examined the use of sufficient ammonium carbonate to bring about complete coagulation of the clay, has resulted in the partial precipitation of organic matter also. In some instances the coagulated clay, after washing with a dilute solution of ammonia containing ammonium carbonate, until no residue was left upon evaporating a small portion of the filtrate to dryness, still contained organic matter soluble in 4 per cent ammonia, thus showing that some humus may be precipitated along with the clay by ammonium carbonate.

In this connection, the question arises as to why it is that ammonium carbonate will completely coagulate the clay in some soil solutions, while in others little or no coagulation takes place. The use of 0.5 gram of ammonium carbonate per 100 cubic centimeters has been found to completely coagulate the clay in Texas[1] soils, whereas in Hawaiian soils little or no coagulation takes place. With the use of considerably larger quantities of ammonium carbonate, however, a complete coagulation takes place in some soils, while in others only partial coagulation can be thus brought about. Alkalis, as is well known, cause a deflocculation of finely divided particles in solution, while acids and certain salts bring about coagulation. It has been found that various calcium salts affect suspension of these soils in water in varying degrees. In some soils a complete coagulation can be produced by a solution of calcium hydrate, carbonate, or sulphate, while in others the carbonate and hydrate have little effect. In solutions containing ammonia such coagulation by lime compounds is uniformly slower.

The behavior of these solutions suggests a fundamental difference in the composition of the clay. As mentioned above, in certain instances ammonium carbonate, at the rate of 4 grams per 100 cubic centimeters, brought about the coagulation of a large part of the clay, but a turbid solution still remained. In such instances the coagulated clay was filtered out and dried and the remaining turbid solution then evaporated to dryness. The residues thus obtained were analyzed with the following results:

Composition of clay from humus solutions.

COAGULATED BY AMMONIUM CARBONATE.

Contituents.	Soil numbers.			
	99.	101.	106.	108.
	Per Cent.	*Per Cent,*	*Per Cent.*	*Per Cent.*
Silica (SiO_2).........	29.00	22.24	25.33	23.80
Ferric oxid (Fe_2O_3)	33.12	37.33	30.42	31.16
Alumina (Al_2O_3).....	37.38	34.93	34.91	37.84

UNCOAGULATED BY AMMONIUM CARBONATE.

Silica (SiO_2)..	38.21	38.29	46.01	[1]
Ferric oxid (Fe_2O_3)	37.39	43.17	32.57	[1]
Alumina (Al_2O_3)..	23.40	18.14	21.42	[1]

[1] All the clay in sample 108 was coagulated by ammonium carbonate.

The composition of the coagulated and the uncoagulated clay is thus shown to be considerably different. In every instance the clay was found to contain relatively high percentages of iron, and that part which was coagulated appears to be made up of a mixture of ferric hydrate and silicate of aluminum, both of which doubtless occur in the humus solution in the hydrated state. The uncoagulated suspension contains relatively more silica and iron, and correspondingly less aluminum. The fact that the iron and alumina were found to be present in about the proportions necessary for the formation of a double silicate, together with the behavior of this suspension, suggests the occurrence of such a compound in these solutions. At any rate, the composition of the clay as expressed above suggests a reason for the failure of the Rather method for the determination of humus in these soils.

GENERAL DISCUSSION.

The results of this investigation show that the percentages of humus found in a given soil may vary greatly, depending largely upon the methods used and the type of soil under investigation. The chief difficulty to be overcome is the separation of humus from clay, and with Hawaiian soils the only method found by which the separation could be made, involved the use of a clay filter. A modification in the concentration of the organic constituents will take place upon passing the humus solution through a clay filter, but this can be overcome by first making the solution to volume then drawing a definite aliquot through the filter, followed by (drawing through the filter) a dilute solution of ammonia until the filtrate contains no organic matter. With the use of a clay filter, modified as previously outlined, concordant results can be obtained, and by a little experience, the details of manipulation can be so perfected as to require a minimum of attention. It is believed that this method can be applied to any soil, and being both practical and accurate, and at the same time involving the use of ordinary laboratory equipment, it can be found useful in any ordinary soil laboratory.

The difficulties attending the use of a number of the older methods are due to the nature of the clay itself. Clay is a very general term, and is usually separated from the other particles by methods which take advantage of the fact that it will remain in suspension for some time, but the exact chemical and physical properties of clay are very variable. The term clay, as used in mechanical soil analysis has reference to the fineness of division, and when unqualified, has reference to no other property. In Hawaiian soils the clay is composed of a mixture of substances which mixture varies between wide extremes. In some instances there is evidence of the existence of a double silicate of iron and aluminum which compound is extremely finely divided and resists coagulation to a remarkable degree. The clay of practically all Hawaiian soils contains a large percentage of iron, a part of which exists as ferric hydrate. This ferruginous character makes the clay extremely difficult to remove from the solution, but enables the analyst to determine whether all the clay is separated from the humus by means of the red color imparted to the humus ash. When the separation has been complete, the humus ash is usually gray. In humus determinations it is of great importance also to know the mechanical structure of the soil, for the applicability of the various methods depends very largely on the type of soil. Attention is also called to the necessity for reporting the humus ash. From the recent investigation of Wells and others,[1] the use of a centrifuge gives promise of wide application in humus determinations, but unfortunately, these authors did not report either the mechanical composition or the humus ash in the soils examined. So long as humus determinations are made without showing the percentages of humus ash, just so long will uncertainty be felt regarding the accuracy of the results.

A BRIEF STUDY OF THE HUMUS SOLUTION.

The humus solution contains a complex mixture of substances, and although the general usage apparently does not always take cognizance of this fact, it is well known to be true. In connection with the investigation of methods for the determination of humus, certain observations have been made and a brief study of some of the properties of humus solutions from Hawaiian soils has been undertaken and are briefly reported here.

COLOR OF HUMUS.

The color of humus extract is usually a shade of dark brown or black and frequently the color of the humus solution is used as a qualitative test by which the relative amounts of humus in soils are estimated. The percentages of humus are generally greater in the soil than in the subsoil. In a set of two samples of soil and subsoil from the Haiku district of Maui, the soil was of the dark color and resembled what is usually called clay loam, while the subsoil answers to the description of yellowish clay. The general appearance of these samples indicates far more humus in the soil than in the subsoil. Upon extraction with a 4 per cent solution of ammonia, the resulting solution from the soils, when freed from clay, were dark brown, while the humus solutions from subsoils were of a yellowish straw color. The amounts of humus would ordinarily be confidently expected to be greater in the solution from soils, but the actual determinations showed the reverse condition. The following table represents the percentage of humus as found in these solutions:

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[1] Rather, loc. cit.

Humus in soils and subsoils.

Serial Number.		Humus.	Humus Ash.
		Per Cent.	*Per Cent.*
105	Soil	2.36	0.44
109	Subsoil	2.75	.73
107	Soil	2.50	.32
110	Subsoil	3.03	.73

These soils were taken from fields that had been cultivated in sugar cane some 20 years ago, but which were afterwards used for grazing purposes, until about 6 years ago, when the land was planted in pineapples. Geologically these soils are of recent formation, although the formation is perhaps as old as that of any other part of Maui. The climate is semihumid, the annual rainfall being about 60 inches. It has been many years since the tropical vegitation was displaced by the cultivated species. The pasture lands there are now occupied largely by grasses, principally Hilo grass.

It was found that the solutions from the soil, when diluted three times, gave about the same intensity of color as those from the subsoil without dilution, although the solution from the subsoil actually contained more organic matter than did those from the soil.

PRECIPITATION WITH HYDROCHLORIC ACID.

A method some times used in the determination of humus consists in precipitating the solution with hydrochloric acid. The precipitate thus obtained is often referred to as "humic acid," and by this method so-called pure humus is sometimes obtained. Upon acidifying humus solutions from these soils with hydrorchloric acid, a precipitate was obtained which was separated from the solution by filtration, then redissolved in ammonia, evaporated to dryness, and incinerated. The results thus obtained were as follows:

Organic matter precipitated by hydrochloric acid.

Solutions.	Organic matter.	Ash.	Solution.	Organic matter.	Ash.
	Per Cent	*Per Cent.*		*Per cent.*	*Per Cent.*
Soil..................	0.46	0.08	Subsoil............	0.14	0.12
Subsoil............	.21	.25	Soil................	.54	.09
Soil................	.25	.05	Subsoil............	.17	.20

The amounts of organic matter precipitated from these solutions is here shown to be only a small part of the total organic matter in the same. An interesting point in this connection is the fact that while the humus was found to be greater in the subsoil than in the soil, the percentages of organic matter precipitated by hydrochloric acid were greater in the solutions from the soils. In no instance was there more than 25 per cent of the total organic matter present in these solutions precipitated by hydrochloric acid. The fact that relatively more organic matter was precipitated from the soil solution than from the subsoil solution indicates a fundamental difference in the composition of the solutions themselves.

OTHER PROPERTIES OF HUMUS SOLUTIONS.

It has been observed in the course of our experiments, that not all humus solutions are affected to an equal degree in passing through a clay filter. The ammonia solutions from some soils have been found to undergo little or no change, in so far as the total amount of organic matter which they contain is concerned, while still others become greatly modified. In some instances a change in concentration, equal to almost 50 per cent of the total organic matter present, takes place, and in such instances an increasingly large amount of ammonia is required in the modified clay filter method, in order to insure a complete removal of the organic matter; in other words, some compounds occurring in humus solutions are absorbed and perhaps dialyzed to a much greater extent than are others. This property is in harmony with the common knowledge of organic compounds.

In attempting to coagulate the clay by means of large amounts of ammonium carbonate, it was further observed that in certain instances a flocculant precipitate, afterwards found to be organic, was formed, while in other solutions, which contained equally as much total organic matter, no precipitate was formed. In this connection, it is of interest to note that the precipitates obtained by the addition of certain salts to humus solutions from different soils have been found by Fraps and Hamner[1] not to be proportional to the organic matter in the humus solutions and to vary in some degree when salts of different bases are used.

In the preliminary treatment with hydrochloric acid, the extracts from several soils used in these experiments appeared to contain organic matter, and upon precipitating these with ammania, by means of which the iron is removed, these solutions were found to contain organic matter, in one instance, in considerable quantities.

The humus from various soils has been found to vary greatly in elementary composition. Hilgard[2] points out that the percentages of nitrogen in humus in arid climates is considerably higher than that from humid sections. The writers have found some variations in the percentages of nitrogen in humus from Hawaiian soils when taken from sections where very similar climates prevail. The carbon content is anything but constant. From the results of a number of investigations, the carbon content of humus has been found to vary from 35 to 65 per cent of the humus. With such variation a corresponding variation is found in the hydrogen and oxygen. Similarly, the mineral matter chemically combined with humus also varies considerably. By reference to a previous table (p. 12) it will be seen that the mineral matter in soil No. 74 is relatively much greater than that of soil No. 69, that of the former being found to be 38.5 per cent of humus, while the latter contained 13 per cent. Soil No. 74 was taken from the Parker ranch on the slopes of Mauna Kea, at an elevation of about 4,000 feet, and while this soil doubtless originated under a humid climate, the amounts of rainfall in this section have been very small during historic times. The soil has perhaps been in the process of formation for centuries. Soil No. 69, on the contrary, came from the Nahiku district of Maui, from land recently cleared of a dense tropical jungle, where the rainfall approximates 200 inches per annum. The organic matter in this soil may be looked upon as being in a much less advanced state of decomposition than that of soil No. 74.

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[1] Loc. cit.
[2] Loc. cit.

From the foregoing brief observations, it is apparent that the fundamental nature of humus is extremely variable. Without doubt humus extracts from soil solution contain a complex mixture, susceptible of alteration in varying degrees by the use of simple means, but whose exact composition is far from being understood.[1] The studies reported have been preliminary to a more fundamental investigation of the several chemical bodies which comprise the humus solution.

THE USAGE OF THE TERM HUMUS.

In agricultural writings the usage of the term humus is far from being uniform.[2] The term humus came into use as a result of the announcement of Berzelius in 1838, who claimed to have isolated a definite chemical body from soils called by him, humin, which body he claimed to have definite properties. As has been pointed out by Schreiner and Shorey,'[3] this work was done before the days of modern organic chemistry, and subsequent investigations have failed to establish the presence of such a definite chemical substance. The terms humic acid and humates have come into use from the fact that certain properties of so-called humus were interpreted as indicating the existence of definite derivatives of this hypothetical substance. Recent investigations and the general properties of so-called humus, together with its extreme variability, show that there are, in reality, no such substances in the sense in which they are used.

The definitions of the term humus, as given by various authorities, are far from being the same. Some authorities make the term synonymous with vegetable mold; others refer to it as partially decayed organic matter. Hopkins[1] in a recent address is quoted as saying that humus is the part of soil organic matter that is resistant to decay and that humus in and of itself furnishes nothing to feed plants. In another publication[2] he states that humus means decaying organic matter which contains the nitrogen of importance in soils.

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[1] Soils. New York and London, 1907, p. 135.

[2] With the exception of the recent work of Jodidi (Michigan Sta. Tech. Bul. 4 and Iowa Sta. Research Bul. 1) and that of the Bureau of Soils of the U. S. Department of Agriculture (Buls. 47, 53 and 74), very lettle can be said to be known concerning the chemistry of soil organic matter. It is of interest in this connection that the isolation of the first definite chemical organic body from soils was made by Shorey from a Hawaiian soil (Hawaii Sta. Rpt. 1906, pp. 37-59), which in many respects is similar to soil No. 69.

[3] U. S. Dept. Agr., Bur. Soils Bul. 53.

The definition frequently given of humus is that it is the soil organic matter soluble in dilute ammonia after removing the calcium and magnesium. The indiscriminate use of the term humic acid and humates has no foundation in scientific fact, and while this fact is usually recognized, the usage is such as to imply the existence of definite chemical substances.

In reality, humus is a no more definite expression than is mineral matter, and the use of the designations humic acid and humates has no justification. The fact that mineral bases, like calcium and magnesium, combine with certain soil organic constituents of humus to form precipitates, does not imply that the resulting substances thus formed have simple salt-like properties, nor that the substances with which the base is combined are of an acid nature in a truly chemical sense.

The chemical nature of soil organic matter has been recently extensively studied by Schreiner and Shorey and Jodidi, and sufficient data have already been obtained to show the extreme complexity of the mixture. Until we have more definite knowledge concerning the substances comprising the organic matter of a soil, the specific effect produced by it and the functions performed in the soils will necessarily be guess-work.

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[1] Breeders' Gaz. 59 (1911), p. 558.

[2] Illinois Sta. Cir. 116, p. 5.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN NO. 34

COTTON IN HAWAII.

BY

C. K. McCLELLAND

AND

C. A. SAHR.

The recent attempt at reviving the cotton industry of Hawaii has met with only partial success. There are many reasons why this crop has not been more extensively grown, some of which will be discussed in this report. The profitableness of the sugar industry, the greater hardiness and wind-resisting qualities of rice, sugar cane and pineapples as compared with cotton, their lesser susceptibility to attacks from insects, and perhaps the traditions of the Chinese, which hold them to the production of rice, are some of the factors which have retarded cotton culture in places where the above crops could be grown, while in other places not suitable for these crops, where water was insufficient for rice or sugar cane or soil conditions were unsuitable for pineapples, cotton has been tried and in some cases given up, because the location was unfavorable or because the crop was so badly infested with insects as to be unprofitable, and in some instances both of these conditions caused the abandonment of the crop.

On the other hand the crop in some instances under some conditions has been such as to justify its continuation. The aim of the present report is to inquire into these conditions and give such information as will help the new grower, as well as results which will be of interest to those already engaged in growing cotton.

ENVIRONMENT.

A favorable environment for cotton must be secured. The most important feature of a favorable environment is location.

LOCATION.

Cotton is a heat-loving plant and can be profitably grown only in protected places, where it is not too cold, where there is little or no wind, or where nights are not too cold. Some locations that have been tried preclude any possible chance of profit. In the cotton-growing regions of the South, it will be recalled that the average daily temperature in summer is higher than in Hawaii and in Hawaii cotton culture should be attempted only where temperature conditions approach those found in the South. High elevations are likely to have wrong conditions. However, at 2,000 feet elevation in Kona, Hawaii, where there is virtually no wind, we have received as good staple as we have grown on Oahu under 300 feet, yet there can be no doubt in our minds that, with other conditions equal, cotton will be *more productive* at the lower elevations. In fact the highest yields reported have always been from near sea level. The station has made some experiments at Waipahu, 700 feet elevation, and at Kunia; and other trials have been made in Waipio, about 650 feet elevation, near Wahiawa, and these trials prove without doubt that in such exposed locations cotton will not produce nearly as well as in more protected places. Upon windward Oahu at sea-level, the wind there being warm and steady, better results were obtained than at the above mentioned places, where the wind was colder and broken up into gusts by uneven mountain peaks and gulches. Upon the Experiment Station grounds during windy times it has often been noticed that cotton bolls would be produceed only upon the leeward side of the plants, on plants that were particularly exposed. With Sea Island cotton in a protected place in 1910 individual plants yielded about one pound of seed cotton. Seed was taken from selected plants of this plat

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and planted upon slightly higher and more exposed land, and in 1911 this planting yielded less than two-thirds of a pound of seed cotton to the plant, which affords evidence of the lessened yield under more exposed conditions.

MOISTURE.

Under Hawaiian conditions all cottons are, or tend to become, perennial, and as perennials they have a tendency towards continual growth, accompanied by a continual production of flowers and bolls where the supply of moisture is optimum at all times. In sections where rainy seasons and dry seasons alternate, the usual habit is to make a heavy vegetative growth during the rainy season and produce the crop in the dry season when the vegetative growth is checked. The continued moderate supply of moisture by rainfall or irrigation, with its consequent continual fruiting of the plant, work against economical production of the cotton, in that repeated pickings,* which are costly, are required, yet the total annual production might be greater where such conditions exist.

Where the rainfall is excessive and continuous the cotton plant will produce but little and will make an excessive vegetative growth. The Caravonica variety in particular under such conditions has a tree-forming tendency.

Another apparent influence of moisture was noticed upon our Sea Island cotton. During the dry weather in 1911 the soil became checked with deep, wide cracks. When the first picking was made in the last of August, and to some extent also in the second picking in September, the individual locks were not open or flushed and the lint was a trifle shorter than it should have been. After a few good rains the third picking was taken off in October and was greatly improved in these particulars. Further observation will be necessary to confirm these conclusions, since the better state of the cotton may have been due to other causes.

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*Under conditions at Makaweli, Kauai, a crop was picked and the plants dormant by the first week of August, while at the Experiment Station where occasionally rains were had, the pickings were continued into October while the largest pickings of the year, as will be seen from table I, were obtained on September 8th and September 16th. The variety in both cases was Caravonica.

SOILS.

The character of the soil upon which to grow cotton seems to be of much less importance than the other factors already mentioned. Cotton is now being successfully grown upon all types of soil, from the heaviest clay to the lightest sands along the coast. Provided that the soil has moisture and a fair degree of fertility cotton can be grown. Even where the soil moisture is too brackish for other crops up to a certain limit, cotton will thrive.

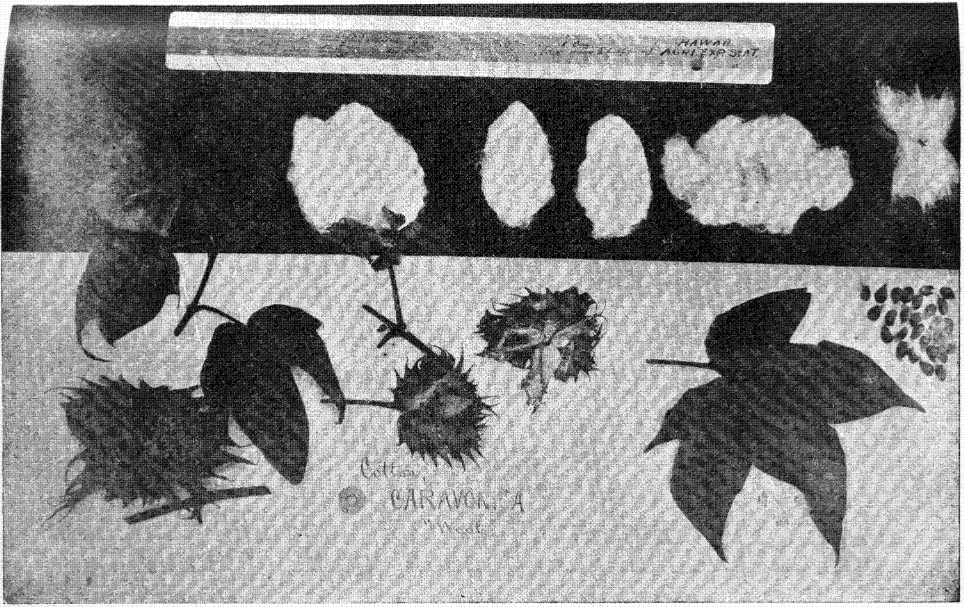
VARIETIES.

Of the different varieties of cotton which have been tried at the Experiment Station, only the Caravonica and Sea Island varieties have been tested sufficiently to justify the publication of any results.

CARAVONICA.

This variety was originated in Australia, but seems to be one of the better varieties under Hawaiian conditions. It is of hybrid origin and the variety is open to criticism in many particulars, but the greatest objection to it is its variability. The majority of the plants are upright in their habit of growth, but many prostrate forms may be found. Some plants are very prolific, producing 500 to 1,000 bolls, while adjoining plants with equal chance may produce less than 50. Some seeds are tufted, some smooth, some more or less fuzzy and some are held together as in "kidney" cotton. The fiber varies from one to one and five-eighths inches in length. It may be very rough or it may be equally smooth, and the percentage of lint may vary from 28 to 44 per cent.

The soil should be well prepared for Caravonica and there should be a reasonable amount of moisture in the soil before planting. Usually early spring is the better time at which to plant, but the ocurrence of rains (or supply of water where the moisture is under control) may better determine the planting season. Under dry conditions a good irrigation before planting would be advisable, in order to hasten germination and get the plants well started. This variety has been thought to be shy in bearing in its first year and it usually is, but when it has a proper degree of heat and plenty of moisture while young it will pro-



Seeds of Caravonica are usually smooth with tuft at one end; the bracts are large; the bolls, usually three locked and opening widely allowing cotton to fall out.

duce well for the first season, although the plants will not uniformly do this. One plant at our rice trial grounds, King street and Kalakaua avenue, from seed planted in March, 1911, yielded four pounds of seed cotton within nine months. This, of course, is exceptional and shows the possibilities of the first year, from seed of good stock, and under best conditions of heat and moisture.

The distances at which to plant this variety will vary with the conditions under which it is to be grown and which determine the size of the plant. Eight by seven, eight by eight, and nine by seven are the usual distances, but in some locations as much as ten feet between rows may be advisable. To secure a stand, plant several seeds in a hill, and where cutworms are found, encircle the hills with a sprinkling of poisoned bran. Later on the hills should be thinned to a single plant. Cultivation should be given at such times as will keep the ground free from all weeds and conserve the moisture. Early cultivation will induce a deep rooting of the plant, and irrigation at this stage is inadvisable. The cost of cultivation will in the end largely determine whether or not the crop will be a success. and it is hardly to be expected that rough and rocky places, where handwork alone is possible, will yield any profit in producing cotton.

During the first year it is possible to grow some other crop between the rows. Cow peas, peanuts, garden peas, soy beans, watermelons, potatoes and other crops have been grown, but it is advisable to grow only short-season crops, so that the ground will not be occupied for any length of time.

PICKING.

When the bolls commence to open frequent pickings are necessary. The bolls open wide and the locks flush out, and there is no cotton exhibiting a more beautiful appearance than Caravonica when showing a considerable number of open bolls. However, if the bolls are allowed to remain too long after opening, rain, winds, birds and gravity get in their work and the cotton will soon be upon the ground. In regions of no wind or storms of any kind it may be possible to have three or four weeks between pickings, but ordinarily eight to fourteen days between is all that should be allowed. Where clean culture for the control of boll worm is practiced, better results will no doubt be obtained by the more frequent pickings. In 1911, under our conditions, the average interval between pickings was about eight days. The amount which can be picked in a day depends upon the amount of cotton open, which in turn depends upon the season of the year, the length of time elapsed since last picking and the prolificacy of the plants. In other words, the amount picked depends upon the amount of surface, both of ground and plant, which the picker must cover in a given time. A willing, experienced and active picker of course has an advantage over those less willing and the slow and awkward. Another feature that must not be overlooked is the amount of moisture at picking time. Pickers often insist on picking when the cotton is damp so as to increase their weights, but only dry seed cotton should be paid for. The largest amount reported for one picking was 125 pounds, but in this case there was admitted to be 50 per cent moisture present. Seventy-five pounds of dry seed cotton will be found to be a high average daily picking for labor here obtainable. With more experienced help and more energetic help this figure should be exceeded. One dollar per hundred pounds is the minimum wage paid, but the average price for dry seed cotton has averaged above $1.50. Unless perfectly dry when picked, the cotton should be well dried before storing in bulk; otherwise it may be injured.

Caravonica cotton is used largely in mixed woolen goods, where long, rough, strong fiber is required. The length, as given above, varies from 1 to 1⅝ inches. The average breaking strength as given by the Department at Washington is nearly 9 grams, while that of short staple Upland cotton is about 7 grams and of long staple Upland cotton between 4 and 5 grams. Because of this greater strength many think the Caravonica could be ginned without injury upon the saw gin. We have submitted sample bales of both roller and saw ginned cotton to an Eastern firm for examination and report. With a two horsepower gasoline engine, a small 14-inch roller gin, at 120 revolutions per minute, had a capacity of about 14 pounds of lint per hour. With hand power, at 45 revolutions per minute, the gin has a capacity of only about 7 or 8 pounds per hour. With same engine a saw gin with ten 12-inch saws, at 250 revolutions per minute, ginned 40 to 50 pounds of lint per hour. This shows the relative capacity of these two gins. However, the percentage of lint obtained from the roller gin varied from 1 to 2 per cent higher than cotton from the same lot when ginned upon the saw gin. Thus, while the saw gin has a much larger capacity, there results a loss (in a 40% cotton) of 2½ to 5 per cent of the fiber when ginned upon a saw gin. It should be kept in mind that for long stable cottons saw gins should be run slower than for short staple cottons, or at a less speed than usually recommended in gin catalogues. The gasoline to run this engine cost about 4 cents per hour. When the cost of operation by gas power is compared with the cost of hand labor, and when it is known that even two men cannot keep the gin running steadily, it will be seen that power ginning is much cheaper than hand ginning, and it will probably pay the small grower to hire ginning done rather than to use hand power machines.

BALING.

There is no uniform size or shape to be found among the bales in Hawaii. Round bales and rectangular bales, both from manufactured and home-made presses are to be found. For round bales, sacks made of wool pack, 3½ feet in diameter and 7 or more feet long, are used. For square or rectangular bales, a poorer quality of bagging can be used, with ropes or wire ties. From 300 to 500 pounds should be put in a bale, and the bale should be protected from the weather.

TABLE No. I

.72 Acres

1911 Record of 306 Caravonica Plants				Early Pruned. Cut Back December 5, 1910					
No of Picking	Date of Picking	Infested Bolls	Good Bolls	Seed-cotton Pounds	Lint Lbs.	Seed Lbs.	Per Cent Lint	Bolls per lb. seed-cotton	Per cent Infested
Preliminary	May 24	....	45	.45	.16	.29	37.5	99	....
1	" 31	318	132	1.38	.51	.87	37.5	94	70.6
2	June 9	409	418	5.47	2.08	3.39	38	75	49.5
3	" 17	378	1075	13.5	5.01	8.49	37.1	78	26
4	" 24	652	973	14.45	5.74	8.71	39.7	67	39.9
5	July 5	665	3788	39.35	15.71	23.64	39.9	96	14.9
6	" 12	590	5382	60.4	23.8	36.6	39.6	89	9.8
7	" 20	727	5790	65.55	24.79	40.76	37.8	88	11.1
8	" 26	534	6767	75.61	28.60	47.01	37.8	89	7.3
9	Aug. 2	616	5856	58.88	22.76	36.12	38.6	99	9.5
10	" 11	121	3707	41.2	16.48	24.72	40	89	3.1
11	" 17	178	4041	44.53	17.43	27.10	39.1	91	4.2
12	" 26	686	6712	73.22	29.08	44.14	39.7	91	9.2
13	" 31	399	7469	78.64	31.71	46.93	40.3	94	5
14	Sept. 8-9	594	9158	94.86	39.25	55.61	41.3	96	6
15	" 16	322	10813	112.37	45.87	66.5	40.8	96	2.9
16	" 22	140	4994	53.62	22.81	30.81	42.5	92	2
17	" 29	302	5588	50.25	20.50	29.75	40.7	111	5.1
18	Oct. 10	119	2627	27.43	11.62	15.81	42.3	95	4.3
19	" 20	67	1260	10.48	4.33	6.15	41.3	120	5
Final	Nov. 10	283	2228	17.25	6.5	10.75	37.6	112	2.7
TOTAL		8100	88823	938.89	374.74	564.15	Av 39.9	Av. 95	Av 8.3
From unnumbered plants					8 06				
				TOTAL	382.8	or 531 lbs. per acre.			

Caravonica fiber sells upon the market at prices varying from 15 to 25 cents per pound, depending upon the year, the demand and supply, and the length, quality and cleanliness of the cotton. The yields per acre upon the Station grounds from one-year-old trees which had been pruned in December, 1910, was at a rate of 531 pounds of lint per acre. Upon similar trees pruned in March, 1911, the yield was only at the rate of 363 pounds per acre, the average yield upon the field being 448 pounds per acre, which is approximately four times the yield that was obtained from the same field in 1910. The Kaneohe Cotton Company reported an average of less than 400 pounds lint per acre from plants in their second year from an area of 13 acres, but a large percentage of their crop was lost through bollworm and also by a fungous disease of some kind. Under better conditions near Pearl City, much heavier yields have been secured, and a report of this planting will be given in another place. Tables I and II give yields by pickings, with the percentages of lint and of worm infestation, and showing the number of bolls per pound at different pickings.

TABLE No. II

.70 Acres

Late Pruned March 1-4, 1911.

Spring Crop

No. of Pickings	Date of Picking	Infested Bolls	Good Bolls	Seed-cotton Pounds	Lint Lbs.	Seed Lbs.	Per Cent Lint	Bolls per lb. Seed-cotton	Per Cent Infested	Length of Lint in 16th of an Inch
1-4	Jan. & Feb.	2307	13241	108.	39	69	Av 36.1	Av 122	Av 19.5	
Fall Crop										
1	Aug. 11	52	1420	16.96	8.51	10.45	38.3	83	3.5	
2	" 17	43	1181	13.78	5.31	8.47	38.5	84	3.5	20
3	" 26	84	2128	25.06	9.75	15.31	38.9	84	3.7	
4	Sept. 1	174	4320	43.52	17.08	26.44	39.2	100	3.8	21
5	" 9	257	9778	100.50	40.75	59.75	40.5	97	2.6	
6	" 17	243	10946	114.75	45.85	69	39.8	95	2.1	22
7	" 23	215	4181	39.75	15.25	24.50	38.8	104	4.9	
8	" 30	295	10316	92	36	56	39.1	112	2.7	22
9	Oct. 10	82	4637	40.62	15.12	25.50	37.4	113	1.7	
10	" 20	160	2270	20.28	8.44	11.84	41.5	110	6.5	21
Final	Nov. 10	234	2143	20	7.25	12.75	36.2	107	9.8	23
Total Fall crop		1839	53320	527.22	207.21	320.01	Av 39.3	Av 101	3.3	
Total Spring and Fall crop		5046	66561	635.22	246.21	389 01	" 38.7	" 104	7	
From unnumbered plants					8.06					
Total					254.27	or 363 lbs. per acre				

PRUNING.

When pruning back the plants, clean cuts should be made with saw or shears. Pruning is practised to aid in worm control, as previously stated in Press Bulletin No. 32, but even without worm conditions it would be necessary in order to control the size and shape of the plant; otherwise the expense of picking would in time be prohibitive. It is necessary, also, to maintain the quality of the fiber, since this usually deteriorates in neglected plants. For how many years it will be possible to renew the plants has not yet beeen determined. Whether to prune high or low, or when to do one in preference to the other is also yet unknown, other than the general rule that the shorter the time that is to elapse before a good fruiting season, the higher the pruning should be made. Table III gives results from two plats pruned at 2 and 4 feet, respectively. This pruning was done in December in the rainy season, and one method was practically as efficient as the other. The figures have been given showing the comparative yields from the early and late prunings made here. An experiment in light pruning or pinching back the new branches at different times during the growing season was tried, but the greatest benefit came from restricting the height of the plant. It was thought that pinching back would induce the growth of fruiting branches and increase yield while at the same time restricting vegetative growth, but Table III shows that no great difference in the yield resulted.

TABLE No. III

Results of Pruning Experiments. Caravonica "Wool."

Pruned high and pinched back at time of	Infested Bolls	Good Bolls	Seed-cotton pounds	Lint Lbs.	Seed Lbs.	Per cent Lint	Bolls per lb.	Per cent Infested	No. of Plants
Squaring	1769	14597	159.4	64.08	95.32	40.3	91	10.8	52
Flowering	1282	14459	151.73	60.23	91.5	39.6	94	8.1	51
Check	1731	14513	160.09	63.85	96.24	39.8	89	10.6	48
Total	4782	43569	471.22	188.16	283.06	39.9	91	9.6	
Low pruned and pinched back at time of									
Squaring	920	13898	150.24	60.19	90.05	40.	91	6.2	51
Flowering	869	13354	141.65	56.58	85.07	39.9	92	6.9	51
Check	1117	15004	156.16	62.17	92.99	39.8	96	6.9	53
Total	2906	42256	448.05	178.91	269.11	39.9	92	6.4	306

The cost of pruning, as reported from different growers, has varied from $2.50 to $5.00 per acre, while upon our own planting it amounted to about $5.70 per acre. The cost will depend largely upon the rankness of growth of plants and somewhat upon the height of pruning, since when pruning high more cuts per tree will be required. To remove pruned branches from the field one man has devised a sled with a rack, which is drawn betweeen the rows by a mule, and the pruned branches are placed thereon at the time of pruning and hauled at once to the sides of the field where they can be burned.

SEMI-ANNUAL PRUNING—TWO CROPS PER ANNUM.

This is a practice that is possible only where the very best environment is present and where some conditions are under control. Mr. E. C. Smith, a pioneer cotton experimenter of Pearl City, Oahu, has succeeded in producing two crops per year for the past two seasons. (Mr. Smith was also the first to practice and advise budding of Caravonica so as to secure better uniformity.) His method is to pick off a crop in June and July and immediately prune back the plants and give enough irrigation to start a new growth. This new growth under his conditions makes a crop in December and January, when another pruning is made, resulting in another crop in June and July. To secure this result he has conditions as follows:

(a) Elevation not over ten feet.
(b) Perfect protection from wind, secured by surrounding fringe of algeroba trees.
(c) Few cloudy days, so that full benefit of sun's rays is received.
(d) Possibly some slight benefit of deep sub-irrigation, but surface soil is generally excessively dry.
(e) A small area.
(f) Water to start new growth in July or August or in February if rains fail to come.

Upon three-year-old plants pruned in July of 1910 a winter crop of 2.5 pounds per tree was obtained, while in the following July 4.7 pounds were picked, making a total of over 7 pounds seed cotton per tree for the year. All cotton opening upon pruned branches within two weeks after pruning is included.* This plat consisted of forty trees, planted 8x7 feet; or at a rate of 778 plants per acre, and the yield was at an annual rate of more than 2,000 pounds lint per acre. No doubt these plants can exceed this record, since their productiveness to date has increased with their age.

However, because of worm infestation—largely from neighboring neglected fields—the winter crop for 1911-1912, although promising good returns, was practically a failure, and the plants were pruned back in December in order to destroy the worm and no winter record is obtainable.

This two-crop method is certainly worthy of more complete trial and should be tested by growers who have similar conditions. One thing is certain: that where anyone can follow this practice, and provided his neighbors do likewise, the worm can be controlled at nominal expense and the crop assured.

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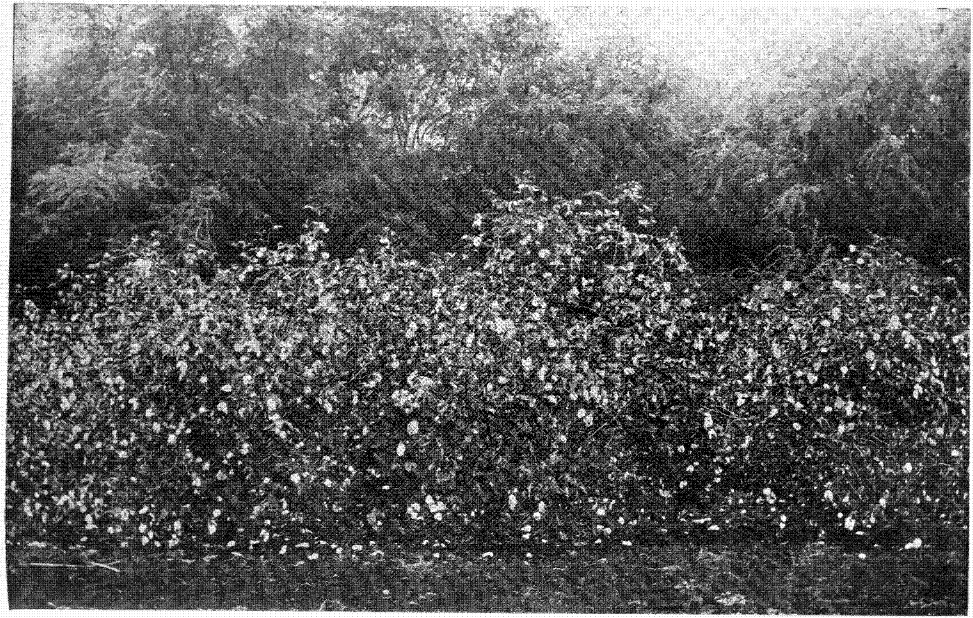
*Cotton opening on branches after pruning shows deterioration. The longer the time elapsing before the opening of the bolls, the greater the deterioration. Only that which is fully open within about ten days is worth saving—at least for spinning purposes.



A result of semi-annual pruning—field of E. C. Smith, Pearl City,
July 1st, 1911.
2.6 lbs. seed cotton were picked from each plant at this time.

SEA ISLAND COTTON.

What has been said about environment for Caravonica cotton is also in the main true for Sea Island. This variety probably will not do as well upon the heavier soils as does Caravonica or as it will upon soils of medium character.

Good location in hot, protected places is important, but the general opinion has been that Sea Island will thrive at higher elevations than will Caravonica. The Station ginned a small shipment that was grown at Honaunau, Hawaii, and found it to be of excellent quality. However, the higher yields with Sea Island are likely to be from places near sea level, where the maximum temperature aids in the full development of the crop. The director of this Station has said that he never saw such productive Sea Island plants even in the Sea Island belt as he has seen at Waianae, Oahu.

Sea Island is not so likely to prove as drouth resistant as the Caravonica cotton, a medium supply of moisture during its entire growing period being more necessary. However, under dry conditions where moisture has been conserved by timely and frequent cultivation a fair crop is obtainable. The plants must be planted at least five feet by four, and under best conditions five by five, six by four or six by five may be preferable.

PICKINGS.

Sea Island cotton does not require as frequent picking as does Caravonica, since the bolls open but partly and the cotton does not flush out as in Caravonica or in Upland cotton. While this is true in regard to number of pickings, yet the expense of picking is likely to be about the same, because, with the partly open bolls, the cotton is harder to pick and less can be picked in a day (25-50 lbs.). The seed cotton should be well dried before storing. Sea Island cotton must be ginned upon roller gins. It can be ginned slightly faster than Caravonica. By increasing the number of revolutions to 130 per minute, our small gin showed capacity of 22 pounds per hour. Using hand power, with two men turning, 45-50 revolutions only are possible, which gives a capacity of about 8 pounds per hour. The increased cost of ginning is self-evident.

It is hardly to be hoped that Hawaii will compete with the

Sea Island belt in producing the quality of cotton known as Fine or Extra Fine Islands, which grades bring the highest prices of any cottons (30-60¢ per pound). We may not be able to produce the required length of staple, our growers cannot within a score of years acquire the knowledge and experience necessary for the proper handling of the cotton, and furthermore the demand for these grades is now fairly well supplied. However, we can compete for the classes known as "Floridas" and "Georgias," which command prices ranging from 20¢ to 35¢ per pound.

PRUNING.

In pruning Sea Island cotton only low pruning should be practiced, since the new growth comes from buds developed upon the lower trunk or near the base of the vegetative branches. Under wind-free conditions usually no vegetative branches are produced.

Whether Sea Island can be grown profitably as a perennial has yet to be demonstrated. It was originally a perennial plant, but grew larger than the present improved type, while producing less and greatly inferior staple. It would seem from the trials at this Station that the first crop has always been the best. This fact might be due to some factor within the plant itself, but we have observed that in the second year the plants are so badly attacked by insects that their vitality is injured, the bolls become smaller, and many may not mature properly, while in such bolls of course the lint would be greatly reduced in value; and the bollworm particularly has been the cause of the loss of the second crop.

The annual report of this Station for 1910 assigns the failure of the second crop entirely to bollworm. Upon another small plat of Sea Island in 1910 the plants yielded more than one pound of seed cotton each for a first crop; but in 1911 the cotton was so badly attacked by mealy bug that the plants were weakened, and, the bollworm aiding in the destruction, no records were taken. Similarly another new planting, an acre in extent, in 1911 produced a fair crop of 293 pounds of lint; but at this date, March, 1912, the mealy bug and bollworm are both in evidence again.* If now the same result is obtained in 1912 as in

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*Since the above was written the infestation in our Sea Island cotton became so great that it was deemed advisable to pull up the plants and plant a new crop. By so doing we hope to extend the time of "no food" for the worm and thus hold them in check until much later in the year.

1910 and 1911, we shall conclude that this variety had best be grown as an annual. This may be also the solution of the bollworm problem, as has been mentioned elsewhere.

YIELDS.

At different times and from various places, but upon small areas only, good yields of this variety have been reported. Even as high as 700 pounds of lint per acre are recorded, but such yields cannot be expected upon a field scale. Upon Maui, at 700 feet elevation, in 1911 a yield of 160 pounds of lint per acre was reported upon a four-acre field. It is doubtful if such a low yield will be profitable.

TABLE No. IV

Sea Island Cotton. 1 Acre.

1911.

Section	No. of Pickings	No. of Bolls	Pounds Seed Cotton	Average Per Cent Lint	Pounds Lint	Pounds Seed	Average number bolls per pound seed cotton	Average per cent Infested
1	4	31482	193.68	28.6	55.43	137.25	162	6.1
2	4	27510	183.86	28.	51.58	132.28	149	15.8
3	4	33993	195.	28.8	56.28	138.72	174	15.9
4	4	45566	283.62	29.7	84.34	199.25	160	22.8
5	4	27005	159.5	28.	44.75	114.75	169	* 25.4
Total					292.38			

* At the beginning of each picking the percentage of infestation was low; i. e. in Section 1.

With plenty of bollworm present, as shown in Table IV, and at 250 feet elevation, an acre upon the Station grounds produced 293 pounds of lint, as given above. These are the only figures available from fields of an acre or more in extent. However, as there are many locations more suited to the crop than those herein given, such as Waianae, Oahu, or Kona, Hawaii, better yields surely are obtainable.

COTTON AS AN ANNUAL OR AS A PERENNIAL.

Whether to grow cotton as an annual or a perennial is a question to be answered only with knowledge of the conditions of the locality under consideration. Caravonica cotton, all experiments demonstrate, increases its productiveness in later years over that of the first, so that in locations best adapted to Caravonica one should grow it as a perennial.

The difficulties in producing annual cotton are mostly included in the statement "hard to secure a stand." Lack of moisture for germination and attacks of cutworms are the principal causes for lack of stand, but later in the season the lack of moisture might result in diminution of yield. Annual plants, not being so deeply rooted as older plants, would suffer more from extreme drouth than would perennials. So that where extremely dry conditions prevail and water cannot be had, difficulty in securing a stand and reduced yield in first year would indicate that cotton as a perennial is preferable.

On the other hand, where there is a pronounced rainy season annually and a stand is easily secured, an annual cotton may be better. Under these conditions it may be possible, by deep, thorough preparation of soil and thorough surface cultivation, to retain in the soil sufficient moisture for the maturing of the crop.

Furthermore, as a means of controlling the bollworm the growing of annual cotton has decided advantages over the other practice. Under this plan and under our conditions, where cotton is best planted in February or March and where it is all harvested by November 1st or earlier (depending upon variety), by completely destroying all plants in November the bollworm is absolutely without squares, blooms or bolls for food until in May following when the new crop begins to bloom. Under the dry conditions of the winter of 1911-12, upon plants cut back December 1, 1911, blooms appeared February 10th and plenty of worms were found by February 19th, so that, although this may be an extreme case, an interval of absence of worm of only ten weeks was secured. An interval of sixteen to twenty weeks before new blooms appear would be much better, although at that infestation from ornamental plants in Honolulu would be possible here.

As noted in another place, Sea Island cotton seems to thrive better as an annual. Upland and Egyptian varieties have usually been grown as annuals, and further experiments are necessary to determine whether or not they would be more satisfactory as perennials. Prunings from perennial plants should be destroyed.

Annual plants should be burned or turned under deeply at the close of bearing season.

HANDLING THE CROP.

To secure the highest market price for cotton considerable care is necessary in handling the crop. In the first place, pick only from fully opened bolls, as the cotton in partly opened bolls is still immature, and cotton that is immature shows a large percentage of waste when worked up in the mills. Pick at such intervals as will allow little or none of the cotton to fall to the ground, as such cotton will be more or less discolored and will pick up a quantity of dirt with it. Stained cotton, leaves, dirt or foreign matter of any kind lower the grade of the cotton. Keep out the leaves and dirt and put stained and worm-eaten cotton in separate bags. Stained cotton can be sold readily at the mattress factories in Honolulu, and it will profit the grower to accept a medium price for such cotton here, rather than to include it in his bale and lose possibly a cent per pound upon the bale because of it. Dry seed cotton before storing; otherwise it might heat and damage the staple. Also see that it has not reabsorbed too much moisture again at ginning time. This would happen only during a wet spell of weather or in regions continually damp.

When these precautions have been well observed and the cotton well packed in bales of 300 to 500 pounds, the grower has a right to expect a good price for his cotton.

The cotton that is sent out from Hawaii will have to be gotten down to a better degree of uniformity and guaranteed if the best prices are to be realized and a demand created for the Hawaiian product. In the Sea Island belt, for instance, many of the growers put out such a uniform staple, clean and correct in every particular, that their name upon the bale is a sufficient guarantee as to its contents. Furthermore, they usually put their early and later pickings in separate bales; they sort the seed cotton before ginning, and pick out the "nep" or knots and any yellow cotton that may have passed through the gin. For this trouble they are paid several cents a pound above usual market price. Similarly, many mills prefer Egyptian to home-grown long staple, since the former has been hand sorted and the waste is usually several per cent less. In order to make a name for Hawaiian cotton most of these precautions should be rigidly observed.

IMPROVING THE CROP.

The preliminary step in improvement is to prevent deterioration. Grow but one variety in the same field. Cotton is easily cross-pollinated, and insects, especially bees, carry pollen from one variety to another, even when these are separated by considerable distance. Upon the Station grounds it has been almost impossible to maintain a pure variety, because it has been necessary to try so many kinds, but where cotton is to be improved every effort should be made to prevent accidental crossing. With annual cottons especially, deterioration from this source might be very rapid. Upon the other hand, where cross-pollination does not occur, the annual cottons are subject to more rapid improvement by judicious seed selection. Another important thing to do is to pull up all inferior plants, and especially those producing short, uneven lint or naked seeds. Also destroy any plants which show themselves to be of a different variety from that supposed to have been planted. Many hybrids may be recognized early by their different habit of growth or by leaves; others by character of flowers.

SEED.

Seed should always be selected, since there is always such a great variation in plants, and only by seed selection can the seed be obtained from those varying for the better. Select from plants having a long, uniform staple; high per cent in lint; and prolific habit. These should be the prime requisites, although shape and size of plant or leaf, character of seed, earliness and other qualifications might be considered. If it is impossible to select enough seed for immediate needs simply plant the selected seed in the field in a given place each time and from this place make further selections: but use the balance of seed in planting the main field and within a few years a great improvement will be noted.

Although good cultivation and proper conditions of plant food and moisture do much to maintain quality and yield, a real improvement in a variety must be made through the seed, either by selection alone or by crossing, with selection.

With perennial cotton, results can not be obtained so quickly for apparent reasons, and yet for ultimate improvement the same method must be followed and the same precautions observed. With Caravonica cotton which has been much decried because of its lack of uniformity, a more uniform product may be obtained by vegetative production; i. e., by buds or cuttings.

CUTTINGS.

Cuttings may be made from the branches of the cotton plants, rooted in the sand bed, and the young plants transplanted to the field. If cuttings are made from only those plants that are uniform in the essential requirements, then the crop which is picked from such plants will be greatly improved in uniformity over the crop from plants grown from seed. Practical uniformity would be secured by taking cuttings at the start from only one plant, but a longer period would be necessary in which to secure plants for a given area. Theoretically this is the plan to follow. Practically, however, there are objections to it. From experience here it seems to be very difficult to root the cuttings and a large per cent perish before rooting and secondly, such plants seem to be less vigorous and productive than plants grown from seed, although, being a perennial, this effect would be less noticeable probably in later years. To properly root cuttings, bottom heat which can be secured only in hot beds or green houses, is necessary, and possibly where such conditions are obtainable better rooted and more vigorous plants could be secured.

BUDS.

Mr. E. C. Smith was the first to attempt budding Caravonica and is authority for the statement that were he to plant 100 acres he would bud every plant. By taking buds only from plants uniform in every way, or as stated for cuttings, taking them from only one plant, good results will be quickly secured.

Budding should be done when the plant is young, when the bark slips easily and with dormant buds if possible. Under the best of conditions a large number of failures are to be expected.

(See Annual Report, 1909. Also Bulletin No. 20 for method of budding.)

IRRIGATION.

Where rainfall is very light and likely to be uncertain at critical times, a moderate supply of water for irrigating purposes will be found very beneficial. Although cotton requires less water than our other crops here except pineapples a certain amount is necessary to germinate the seed, to produce a plant of proper size and to insure the proper development of the bolls.

Egyptian cotton has been grown under irrigation more than the other varieties and it is the one upon which the U. S. Department of Agriculture is now conducting experiments under irrigation in Yuma, Arizona, and in California. It is claimed to be less drouth resistant than upland cotton and necessarily then, less so than Caravonica.

While we are conducting no experiments with cotton under irrigation yet from a study of practices elsewhere a few suggestions may be taken. Irrigations should be thorough and should be followed by most thorough cultivation. Do not replace cultivation with irrigation. The first application should be before planting unless the soil is sufficiently moist. This hastens germination and aids in securing the proper stand. Then withhold water and cultivate for several weeks—a month at least—and allow plants to root well and deeply. The number of irrigations will depend upon variety, nature of soil, amount and distribution of rainfall and these conditions vary so within short distances that no exact number can be given. In general it can be said that unless rains occur within six or eight weeks after planting, another irrigation should be given and after that only a small amount of moisture will be needed if proper cultivation is kept up.

A good growth of plant should be secured before any squares are formed and when fruiting begins a slower, steady growth is desirable.

As mentioned in another paragraph Caravonica will not prove as shy in bearing in first year if sufficient water is supplied and also, as stated, the fruiting will be continuous until fall if moderate supply of moisture is obtainable during summer months. Water should be withheld to check vegetative growth and give opportunity for fruiting and also to allow the plant to become dormant before pruning.

If growing Caravonica for two crops annually one watering is necessary before seeding or after pruning and according to conditions another may or may not be necessary during the fruiting season, but if necessary the application should not be excessive.

When an annual pruning only is given, this should be done before the rainy season. When rains are not sufficient to make a good growth of the plant, irrigation should be resorted to and as in the former case, repeat if necessary.

DISEASES AND INSECTS.

A fungous disease of some kind has been noticed upon cotton at Kaneohe and at Pupukea, Oahu. It attacks the bolls, preventing proper maturing and opening. As high as ten per cent of the bolls at some pickings were found to be worthless, the percentage being larger during wet spells. The disease is probabl antracnose although the discolored spots characteristic of this fungus were not always present.

The insects attacking cotton in Hawaii have been described in Bulletin No. 18 of this Station. Press Bulletin No. 32 gives the results in 1911 of cultural methods of controlling the boll worm. Tables I, II and IV give in one column the percentages of infestation in our fields upon different dates. It should be added here, however, that only where frequent pickings are made will such good results as shown in these tables, be obtained.

FERTILIZERS AND ROTATION.

Cotton has been found to respond readily to a judicious use of fertilizers. Where it is grown continuously upon the same land and given the clean cultivation which it demands, there will result a gradual diminution of the humus in the soil and also a reduction of the supply of available plant food. Rotation of crops and the plowing under of organic manures in some form will be found necessary in order to keep up the soil fertility. A further addition of commercial fertilizers will materially increase the yield. Nitrogenous manures should be used sparingly since they tend to increase the formation of wood and delay maturing, and cotton plants here seem to acquire sufficient size. Larger amounts of potash or of acid phosphate may be used especially of the latter since it increases fruitfulness and hastens maturity. Fertilizers analyzing 9 per cent of available phosphoric acid, 2 per cent of potash, and 2 per cent of nitrogen, in amounts varying from two hundred to six hundred pounds an acre, are used largely in the South. The proper proportions and amounts have not been determined for cotton in Hawaii.

The fertilizer should be applied before planting and with perennial cotton any later application can be placed in furrows made close to the plants upon each side of the rows and then covered with cultivators or hoes. Fertilizer distributors are used for such work in the South and are very economical implements since they cost only about $5 each.

For rotation crops, Jack beans, soy beans, cowpeas, or other legumes are preferable although grain or other crops may be grown.

CONCLUSION AND SUMMARY.

Cotton culture in some parts of Hawaii has been abandoned. In some locations this result was brought about because of the damage done by the bollworm; in other regions, because they had conditions ill suited to the best growth of the crop.

A good quality of cotton in paying quantities can be produced under certain conditions.

On the lower elevations; with a moderate supply of moisture; with absence of, or protection from, wind; with a good supply of heat; and in fields that can be given horse cultivation—a good profit can be made in growing cotton even under bollworm conditions.

Because of the bollworm, Sea Island cotton should be grown as an annual, and also only where there is no difficulty in securing a stand.

In drier locations, Caravonica will likely be the better variety and should be grown only as a perennial. Good yields will be obtained from this variety in the first year only where the very best conditions of heat and moisture exist. It requires an occasional pruning, which should be given usually prior to the rainy season. Under certain conditions, two prunings can be given and two crops obtained, and where this is possible greater immunity from the bollworm will result.

Careful handling of the staple is necessary at all times.

A more uniform product can be secured by propagating with buds or cuttings, but only through the seeds is any improvement possible. To secure this, hybridization must be prevented or controlled; all inferior plants or those having undesirable qualities must be destroyed; and seed must be selected only from those which have desirable characters.

In determining what is suitable environment for cotton in the Islands we find that location evidently has far more influence than the character of the soil. Any soil will grow cotton (some, however, require fertilization, and in some perhaps the water might be too brackish), but *some locations preclude any possible chance of profit.*

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Issued June 12th, 1912.

Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN No. 35.

Sisal and the Utilization of Sisal Waste.

By E. V. Wilcox

and

Wm. McGeorge

CULTIVATION AND ECONOMIC RELATIONS OF SISAL.

By E. V. Wilcox.

Bulletin No. 4, published by this station in 1903, covered rather completely the botanical aspects of sisal, the various processes connected with planting, cultivation, harvesting, milling and baling, together with notes on insects and diseases of this crop. The supply of the bulletin has long been exhausted and frequent requests have been received for further literature on sisal in Hawaii. The particular occasion for the chemical investigations reported in the present bulletin arose from the desirability of learning what economic use could be made of the large quantity of pulp which accumulates about the mill from decortication of the sisal leaves. In connection with this chemical work a fresh review was made of the conditions of the sisal industry in Hawaii at the present time.

Sisal was first brought to Hawaii from Florida in 1893. After a preliminary test at Ewa, Oahu, the plant was thought worthy of trying out on a large scale. The Hawaiian Fiber Company was organized for this purpose and has continued the production of sisal since that time. The plant was found also to thrive well on the other islands. Plantings of considerable size were made on Kauai, Hawaii and Maui. On account of the pressure of other industries, however, it was not found desirable to continue sisal production on the other islands, particularly since it was impossible to secure sufficiently large areas which were not adapted to other crops promising a rather larger profit. At present the Hawaiian Fiber Company is practically the only commercial organization engaged in the production of sisal in Hawaii. As just stated, local economic reasons weigh against the great extension of the industry on other islands.

The area at present under cultivation on Oahu is about 2,000 acres, located partly at Sisal and partly at Robinson. There is little possibility of further extension at Sisal, while at Robinson the opportunity for enlarging the area of sisal is fairly good. The profit per acre derived from the cultivation of sisal is rather small as compared with many other tropical crops, and for this reason there is greater need for the cultivation of the crop in large and continuous areas in order to secure reasonable profits. It is generally considered that areas of less than 1,000 acres are not likely to yield profitable remuneration when planted to sisal. Much larger areas, up to 10,000 acres or more, give better promise.

The present output of fiber from the mill located at Sisal is from one-half to one ton per day, depending on whether one or two machines are running. Recently a third machine has been started in operation in the Robinson section of the plantation and the total output will thus be increased accordingly. The baled fiber is an unusually beautiful product, being well cleaned and laid straight and at full length in the bale, so that no kinks are produced in the fiber. The quality of Hawaiian sisal is equal to the very best. In fact, the only sisal which brings an equal price is that which is produced in German East Africa. Recently, for reasons not perfectly understood, the price of sisal fiber was driven down to 4 cents per pound, but it has again recovered to the extent of 1 cent.

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The annual yield, as judged by the results thus far obtained by the Hawaiian Fiber Company, is about 500 pounds of fiber per acre. The sisal plant matures under Hawaiian conditions in from three to four years, and sends up poles at the age of six to nine years. The true sisal seems on the whole to possess qualities making it superior to henequen for Hawaiian conditions. The life of the sisal plant is not so long as that of the henequen, but the quality of the fiber is better and the ease of handling is greater on account of the absence of spines along the edges of the leaves.

Among the more striking results obtained from the practical experience in the growth of sisal on Oahu is the fact of the great advantage of cultivation. If the sisal sucker at proper age and size for planting is merely placed in holes dug in the ground at the usual spacing distance, eight or nine feet, without previous plowing of the soil, the growth is slow as compared with that after plowing the soil. It seems not to be necessary to cultivate the soil after planting, if thorough plowing has been done before planting. At any rate, by merely plowing without subsequent cultivation one full year is cut off from the time required to reach maturity. This is plainly an important matter in the economy of sisal production. In addition to the saving of one year's time, a further advantage is obtained from plowing in that the plants make a more vigorous growth and produce leaves of greater size and length, thus increasing the total amount of fiber per acre. Mr. Wm. Weinrich, Jr., manager of the Hawaiian Fiber Company, has made a careful study of the economy of plowing versus not plowing, and the results indicate clearly the advantage of plowing. There is a still further advantage from plowing, in that corn and other crops may be cultivated between the rows of sisal for the first two years after planting sisal suckers.

Sisal is perhaps the best crop to be recommended for the large area of dry, highly manganiferous soil on the Wahiawa Plains. As has been clearly demonstrated, pineapples do not thrive on soil containing more than 2 per cent of manganese; in fact, even a lower percentage may cause a very unsatisfactory growth of pineapples. On some of this soil corn and other crops make a fairly good yield so long as the normal rainfall occurs and cutworm and leaf hoppers are not too abundant. Many almost complete failures have occurred, however, in trying to raise intercrops in the sisal fields on account of the prevalence of insect pests or the lack of sufficient rain. There is no difficulty connected with the growth of sisal on this dry, highly manganiferous soil. Sisal in its behavior to manganese presents a striking contrast to pineapples. Apparently the reason for the injurious effect of manganese on pineapples is to be found in the fact that the manganese causes an undue absorption of lime and a reduction in the amount of magnesium and phosphoric acid. All pineapples have been shown to be very susceptible to an excess of lime. Manganese exercises the same effect upon sisal as upon pineapples, but the sisal is a lime-loving plant and is not disturbed by the presence of unlimited amounts of lime; in fact, at Sisal the plants are growing in coral limestone with only a mere trace of soil which has been washed down from higher levels.

One of the unexpected results obtained through the chemical examination of sisal is the fact that the normal acid of sisal is lactic. It was at first suspected that perhaps the presence of lactic acid might be a part of the basis of its reacting toward manganese so differently from pineapples. This supposition, however, was not borne out by further investigation, since manganese was found to be fully as soluble in the lactic acid of sisal as in the citric acid of pineapples. While lactic acid has been occasionally found in the seeds of certain plants, sisal is apparently the first plant to be shown to develop this acid as its normal vegetable acid.

The chemical investigations reported in this bulletin will indicate pretty clearly the prospects for the economic utilization of sisal pulp or waste. About 2,000 tons of this pulp has accumulated in the dump heap behind the mill at Sisal, and about 25 tons of pulp are being added per day. In estimating the moisture content of the pulp after standing, it appears safe to reckon it at about 50 per cent. In milling at Sisal it has been found necessary to use water in order to prevent a stickiness and improper cleaning of the fiber. At Robinson the water content of the leaves is somewhat higher and no water is required in milling. Even where water is used in milling, however, it rapidly runs out of the pulp in milling and does not add appreciably to the moisture content of the pulp on the dump heap. Assuming the moisture content of the pulp on the dump to be 50 per cent, the actual fertilizer value of this pulp is about $6.00 per ton. As the chemical investigations indicate, the amount of mineral plant food in the sisal waste is rather high. In addition to its being a mineral fertilizer, there are the nitrogen and humus values to be considered. The feeding experiments that have thus far been made give only slight encouragement to the idea of using the pulp as a cattle feed. Cattle do not apparently take kindly to it, although its aroma and flavor, especially when dried are rather agreeable. It is evident from the chemical investigation of sisal that the value of the plant food in the pulp for fertililzer purposes is greater than the value for alcohol production of the fermentible substances.

The prospects for sisal production on the island of Oahu are at present very satisfactory. Practically all of the milling difficulties have been overcome. The known corrosive effect of lactic acid upon metals gave considerable difficulty at first, but the sprocket chains and other exposed parts of the machine if made out of gunmetal resist the action of the acid in a satisfactory way. There are at present no serious diseases or insect pests to contend with in growing sisal, at least on the island of Oahu. A peculiar disease of unknown nature, causing a discoloration of the fiber, was observed on Hawaii, but has not occurred on the plantations of Oahu.

CHEMISTRY OF SISAL.

BY WM. McGEORGE.

In the process of decortication of the sisal leaf, since the leaves contain only 4-5 per cent of fiber, there necessarily accrues a large amount of waste. For several years the planters of Yucatan, German East Africa, Java, Hawaii and other countries where sisal is grown commercially, have been searching for some possible means of an industrial utilization of this enormous waste. At the solicitation of the Hawaiian Fiber Company, this station undertook a study of the chemical nature of the sisal plant, to ascertain, if possible, some commercial use for their waste. So far as the author has been able to ascertain from the literature at hand, there has been published little thorough chemical work on the sisal plant. F. H. D'Herelle[1] carried on thorough investigations in Yucatan at the solicitation of the Mexican Government. Others have published analyses of the waste to determine its fertilizing constituents, and the Experiment Station at Mauritius has made several unsuccessful attempts to ferment the waste for the production of alcohol.

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[1] Journal d'Agriculture Tropicale, June, 1910.

The economic uses of the various species of Agave date back many years and the methods of utililzation vary between wide limits. The inhabitants of the Central American countries and Mexico took advantage of its saponin content by using it for washing purposes, the fiber for making ropes and stringed musical instruments, the juice as an insecticide and the leaves as fodder for cattle. Agave americana, as well as several other species, at the time it is ready to send up its flowering stalk experiences a remarkable upward flow of sap. This is sometimes collected by cutting out the central bud and leaves and inserting a receiving vessel. By fermentation of this juice the natives prepared an alcoholic drink called pulque.

The two varieties cultivated in Hawaii and the ones to which our studies were mostly confined are sisal and henequen. Our laboratory investigation was confined to the possible use of the residue as fertilizer, as stock food or for the manufacture of industrial alcohol. A short study was also made on the general chemical composition of the plant, and how this composition may vary when affected by different weather and soil conditions; also to determine the nature of the organic acid which causes its strong acidity, and the possible commercial importance of this acid.

FERTILIZER VALUE.

The waste from the mill of the Hawaiian Fiber Company has been accumulating since the beginning of the industry, and at present there is a large quantity of it piled up at the mill. On the first visit of the author to the mill samples were taken from this pile with the view of ascertaining its fertilizing value, as that is undoubtedly the only means of its disposal in this decayed condition. Samples were also taken of the juice coming from the mill and fresh waste pulp as it was being hauled from the mill to the dump. The following table gives the results of the analyses:

ANALYSES OF WASTE PRODUCTS.

Sample No.	Nitrogen	Potash	Phosphoric Acid
	Per Cent	*Per Cent*	*Per Cent*
1.	.45	5.21	2.79
2.	1.35	1.70	1.23
3.	.88	.69	1.20
4.	1.04	1.70	.95
5.	.49	6.38	.67
6.	.93	2.19	.46

No. 1 is a sample of ash taken from the pile (the waste had been partially burned several times). No. 2 represents waste which had been in the pile about six months; No. 3, about one year; No. 4, about two years. No. 5 is a sample of brown powder obtained by evaporating the juice to dryness, and No. 6 is a sample of fresh waste pulp. These analyses are all on air dry samples, and are a fair representation of the plant food stored up in the pile, and clearly indicate the advisability of its being returned to the soil and the possibility of using the fresh waste as fertilizer. Application of the fresh waste would of course mean an addition of nitrogen and humus forming material to the soil, but would offer difficulties in application and transportation. The burning, or at least partial burning, of the waste would mean a loss of a large percentage of nitrogen and organic matter, but this would possibly be offset by the increase in content of mineral constituents and ease of transportation. As shown in the analysis of the ash, which was only partially burned, some of the nitrogen remains in the ash. By returning the waste to the soil in any form, lime, magnesia, potash and phosphoric acid, minerals on which sisal feeds most heavily, will be returned to the soil. Otherwise the land will in time tend to become exhausted.

FEEDING VALUE.

The use of this waste as stock food presents a possible means of its disposal. From the analyses of the sisal leaves the protein content varies from 0.73 per cent to 1.16 per cent on the fresh leaf.[1] The following table shows the minimum and maximum percentages found in our analyses for constituents of feeding value:

FOOD ANALYSIS.

	Minimum	Maximum
	Per Cent	*Per Cent*
Moisture	80.22	88.00
Protein	0.73	1.16
Nitrogen free extract	7.58	13.57
Fiber	2.27	3.32
Ash	1.42	1.73
Ash Ingredients	Per Cent in ash	Per cent in leaf
Potash	10.08—20.64	0.17—0.35
Lime	20.08—45.68	0.36—0.79
Phosphoric acid	1.54— 9.76	0.04—0.14

A qualitative test failed to show the presence of more than a mere trace of fat or oil in the leaf.

The present location of the mill, upon a barren area of coral land, where it seldom rains, would probably necessitate the transportation of the waste, should it be found to be of practical food value. This condition would necessitate its being brought to a dried form, which could be done without materially altering its palatableness and would decidedly increase its food value. The air dried pulp has a very agreeable aroma and physical appearance which it will maintain indefinitely. In the air dried form it will contain about 5 per cent moisture, which state would increase its food value as follows:

Moisture	5.00	per cent
Protein	5.78	" "
Nitrogen free ext	60.01	" "
Fiber	17.97	" "
Ash	11.24	" "

These figures represent the minimum values found in the course of our analyses. In view of the above facts, the dry waste appears the more suitable form to feed and is worth a fair trial as such, especially in view of the scarcity of forage crops in Hawaii.

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[1] For comparison with other feeding stuffs of Hawaii, see Bul. No. 13 of this Station.

CHEMICAL INVESTIGATION.

Since very little chemical work has been done on sisal, it was considered of sufficient importance to make such an examination, especialy to investigate the carbohydrate content with regard to its utilization for fermentation purposes. The carbohydrates to be found in vegetable matter include various sugars, starch, gums, and celluloses. Heretofore, in a great many of the analyses of vegetable matter these carbohydrates have been classified under "nitrogen free extract," a term used quite indiscriminately and having a very indefinite meaning. During late years various articles have been published and numerous reasearches made upon the composition of this nitrogen free extract. W. E. Stone carried on a great deal of work in this line and published a method[1] for the separation and determination of the carbohydrates. This method, slightly modified, proved to give good results when applied to sisal, and was chosen for use in the analyses made in this investigation.

EXPERIMENTAL.

Before beginning the actual analysis a preliminary examination was made to ascertain the character of the ether, alcohol and water soluble matter. About 100 grams of finely chopped leaf was covered with ether in a 500 cc. Erlenmeyer flask and allowed to stand one week with frequent shaking. The extract was filtered off and the residue washed by decantation several times with ether. The extract had a green color due to dissolved chlorophyl, acid reaction and bitter taste. No fat or oil was detected, and on evaporating off the ether the residue was composed largely of a green waxy or resinous substance and contained no crystals. The per cent of solid matter extracted by the ether was very small and contained no sugars.

The residue from the ether extraction was treated in a like manner with 95 per cent alcohol, filtered and the residue washed by decantation. The result of this extraction was a greenish brown solution with slightly bitter taste and acid reaction. On evaporation to dryness there was deposited a greenish black residue of a gummy nature. This alcoholic solution when evaporated to dryness and the resulting residue treated with cold water was found to be almost completely soluble. The water dissolved the gums and sugars, both reducing and nonreducing, and the acid, as on redissolving the residue insoluble in water it gave a neutral reaction with litmus. The residue insoluble in water contained no sugars as it failed to reduce Fehling's solution either before or after inversion.

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[1] Jour. Am. Chem. Soc., Vol. XIX., p. 183.

The residue from the ether and alcohol extraction was next treated in a like manner with water. The solution obtained had a yellow color, acid reaction and fairly agreeable taste. Upon standing several days this solution developed a moldy scum, indicating its ready susceptibility to bacterial growth. It contained reducing and nonreducing sugars and a relatively high per cent of gums. On evaporation to dryness the resulting residue was insoluble in alcohol, benzene, slightly soluble in ether, and formed an emulsion with chloroform. From the above examination it was considered to be unnecessary to make an extraction with ether in the analyses, but it seemed imperative to use the alcohol extraction followed by one with water and then treatment with diastase for the starch determination. It is evident that there is present in the leaf a small percentage of reducing and nonreducing sugars and a large percentage of gums which are insoluble in alcohol and would be acted upon by the acid inversion and subsequently determined with starch, thus giving too high a percentage of starch. This danger is eliminated by extraction with water before treating with diastase.

METHOD OF ANALYSIS.

1. Several fresh leaves were cut up into small pieces and from this 100 grams were weighed into a 1-litre flask fitted with a reflux condenser. Five hundred cubic centimeters of 95 per cent alcohol were added and the whole boiled for three hours. After thoroughly cooling, preferably letting stand over night, the alcohol was filtered off and the residue in the flask washed several times by decantation. This solution was evaporated on the water bath almost to dryness and then treated with water.

By this means the water dissolved the sugars and gums, leaving a residue of resin. The contents of the dish were then filtered through asbestos with the aid of a filter pump and the filtrate made to 200 cc. The resins remaining on the asbestos pad were dissolved in alcohol and the amount determined by evaporating an aliquot to dryness in a tared porcelain dish and weighing the residue. Next the reducing and nonreducing sugars were determined in aliquots of the 200 cc., by titration against Fehling's solution before and after inversion. Total solids was determined by evaporating an aliquot of this solution to dryness in a tared porcelain dish. The solids in solution other than sugars were considered to be gums and were thus determined by difference.

2. To the residue from the alcohol extraction 300 cc. of distilled water was added and allowed to stand at room temperature for 24 hours with frequent agitation. The residue was then filtered off and the solution was made to 500 cc. The reducing and nonreducing sugars were determined with Fehling's solution before and after inversion. Total solid matter was determined in an aliquot of the solution as in No. 1 and gums were obtained by differencce.

3. The residue from the aqueous solution was brought to an air dry condition and its weight accurately determined in order to establish its quantitative relation to the original weight of the leaf. Two grams of this residue were weighed into a 250 cc. beaker, 100 cc. of water added, and the whole boiled for one hour to convert the starch into a soluble form. This was then cooled to 65° C. and 25 cc. of a strong infusion of malt added. The malt was then allowed to act on the starch for several hours at 65° C. and subsequently allowed to remain in a warm place over night. This solution was filtered, the residue washed upon the filter paper and the solution evaporated to 100 cc. This was transferred to a 250 cc. flask, 10 cc. of concentrated hydrochloric acid added and the flask fitted with a reflux condenser and placed in a boiling water bath for one hour. It was then nearly neutralized, brought to volume and its sugar content determined against Fehling's solution. A blank determination was made upon the malt extract and results corrected accordingly.

4. The residue from the malt extraction was removed from the filter, 100 cc. of water and 2 cc. of concentrated hydrochloric

acid added and the whole boiled under a reflux condenser for one hour. The pentosans being in this manner converted into reducing sugars were determined by nearly neutralizing, bringing to definite volume and titrating against Fehling's solution.

5. The moisture, ash, crude fiber and nitrogen determinations were made upon the fresh leaf. Moisture and ash were determind on the same sample by heating 5 grams in the air bath at 100° C. for five hours. The loss in weight was considered as moisture. On this residue the ash was determined by ignition. Crude fiber was determined by drying 2 grams of the fresh leaf in an air bath and treating acording to the Official Method. Nitrogen was determined by the Kjeldahl Method.

The following table gives a comparison of the different samples analyzed, and attention is called to their variation in carbohydrate content:

CHEMICAL COMPOSITION OF LEAF.

	SAMPLE NUMBERS					
	1.	2.	3.	4.	5.	6.
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Reducing Sugars	12.49	18.68	10.45	20.03	7.48	18.50
Nonreducing Sugars	5.58	17.32	27.77	7.56	7.33	2.69
Gums	35.14	15.67	23.48	23.72	34.58	38.51
Starch	.66	2.57	.66	1.80	.64	1.25
Pentosans	2.32	4.92	3.96	4.73	5.95	4.58
Nitrogenous matter	7.25	4.75	4.89	6.00	3.68	5.19
Resin	2.82	.83	1.84	1.53	1.57	1.93
Fiber	20.86	23.13	15.80	23 71	26.49	18.32
Ash (total)	14.42	8.53	9.16	9.14	11.83	14.76
Acidity	....	4.42	3.48	3.94	1.56	....

In this table column 1 is the analysis of a sample of sisal grown at Robinson, Oahu, on a red clay soil; 2 is that of a sample grown on the station grounds, where it received much rain and in a tufa soil; 3 that of a sample grown at Sisal, Oahu, on coral land with very little rain; 4 that of a sample of henequen grown on the Experiment Station Grounds; 5 that of henequen grown at Sisal, and 6 is the analysis of a sample of Agave americana grown on the Experiment Station Grounds. It is thus seen under what varying conditions sisal may be grown with apparent success.

It may be well at this point to insert a table showing the amount of sugars and gums in the fresh leaf.

	1	2	3	4	5
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Moisture	88.00	86.20	81.01	84.30	80.22
Sugar	2.16	4.97	7.25	4.33	2.93
Gums	2.97	1.28	3.36	2.59	5.84

The columns are numbered as in the preceding table.

DISCUSSION OF METHOD AND RESULTS.

1. The extraction with alcohol proved to be a reliable means of dissolving the larger part of the sugars occurring in sisal, which were found to be in large part sucrose, levulose and dextrose. It was found absolutely necessary to allow the alcohol to thoroughly cool before filtering off, for the reason that in so cooling a flocculant precipitate settled out. This was, no doubt, saponin, and if the solution was filtered hot it would precipitate in the filtrate as the solution cooled. Again, in the determination of the sugars by titration against Fehling's solution it was found to be advantageous and in most cases imperative that the gums be removed by precipitation with lead acetate and subsequent removal of the lead with sodium carbonate before titrating against Fehling's solution. Although this procedure consumed considerable time, if it was not followed out a yellow colloidal precipitate was formed when the sugar solution was added to the copper solution. This failed to separate out on prolonged boiling and in this manner obscured the decolorization of the Fehling's solution. On filtering, to test the filtrate for unreduced copper, this yellow colloid passed directly through the filter paper carrying with it reduced copper. By precipitation of the gums with lead acetate and subsequent removal of the lead with sodium

carbonate, this trouble was entirely eliminated. However, in cases where a titration could be made without treatment with lead acetate it was found on making a comparison of the results from titration of a solution treated as above and the same solution untreated, that the latter showed a slightly higher sugar content. In no case was the author able to get results with the polariscope which compared favorably with the results obtained by titration.

2. In every case it was found that the extraction with cold water dissolved sugars which were apparently insoluble in alcohol. Treatment with lead acetate before titration was found to be more imperative in this case than in that of the solution in alcohol, probably due to the fact that the former solution contained a larger amount of gums. It is an interesting fact that the sum of the water and the alcohol soluble matter is a fairly constant quantity except in the case of Nos. 3 and 6, as shown in the following table:

WATER AND ALCOHOL SOLUBLE CONTENT.

	SAMPLE NUMBERS					
	1.	2.	3.	4.	5.	6.
Reducing Sugars—	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Soluble in Alcohol..........	10.83	14.88	8.66	16.62	6.42	16.32
Soluble in Water	1.66	3.80	1.79	3.41	1.06	2.18
Nonreducing Sugars—						
Soluble in Alcohol..........	4.83	12.79	21.50	5.81	5.00	2.28
Soluble in Water..............	.75	4.53	6.27	1.75	2.33	0.41
Gums—						
Soluble In Alcohol..........	15.38	4.80	8.96	7.55	12.75	18.05
Soluble in Water..............	19.76	10.87	14.52	16.17	21.83	20.66

By reference to the table it may be seen that in the cases where the sugar content is high the gums are low and vice versa. In view of this fact several leaves were allowed to remain in the laboratory after being cut for about one month. Analyses were made on the fresh leaf and after standing one month, with the following results:

DECREASE OF SUGAR CONTENT.

	Fresh leaf	Same one month old
	Per Cent	*Per Cent*
Reducing Sugars	18.68	2.97
Non-reducing Sugars	17.32	9.17
Total Sugars	36.00	12.14
Gums	15.67	39.53

Analyses are calculated to moisture free basis, and show the large decrease in sugar content of both reducing and nonreducing sugars, more marked in that of the former, and also the marked increase in amount of gums corresponding to the decrease in sugars. On the leaves which were allowed to remain in the laboratory for some time there was a gummy exudation at the base end. Coupled with this is the fact that it is the general practice at the mill to decorticate the leaf as soon after cutting as possible. Otherwise the fiber is not so easily cleaned. F. H. D'Herelle found that reducing sugars in the sisal leaf increased upon standing, little by little, and reached a maximum on the sixth day.

3. The sisal leaf, as may be seen from the table, contains only a very small percentage of starch. By treatment of a cross section of the fresh leaf under the microscope with iodine, blue spots were few and widely scattered. In view of this fact the solution was boiled vigorously, and after neutralizing a strong infusion of malt was allowed to act for some time to bring all the starch into solution. The solution obtained in No. 2 by treatment with cold water contained no soluble starch.

4. The residue from the starch extraction still contained the actual cellulose or crude fiber and the more complex carbohydrates, such as pentosans, which upon treatment with acid are hydrolyzed into sugars capable of reducing Fehling's solution. From comparative tests the treatment with acid was found to give more concordant results than the method of distillation with strong hydrchloric acid and subsequent determination of furforol obtained in the distillate.

5. In the determination of the crude fiber it was considered necessary to make this upon the original sample according to the Official Method. It was found that the analysis of the residue from No. 4 gave too low results.

CRUDE FIBER.

Sample No.	I	II
	Per Cent	*Per Cent*
1	23.13	17.56
2	23.71	18.30
3	24.52	20.77

Column I shows per cent of fiber obtained from three analyses of the fresh leaf by the Official Method and column II the per cent obtained by analysis of residue No. 4. It was found impossible to obtain good checks on duplicate analyses made by the latter method.

CHARACTER OF THE ACID IN SISAL.

It is a well known fact among those engaged in the decortication of sisal leaves that the juice is very destructive to the metal in the machinery with which it comes in contact and also to the hands of the laborers who handle the fiber as it comes from the machine. In view of this fact, it was considered to be of sufficient importance to attempt to identify this acid and ascertain if it chanced to be of commercial value. So far as the author has been able to ascertain from literature at hand, the character of the acidity has never been determined definitely. M. D'Herelle[1] calls attention to the strong organic acidity of the leaf, which he says is due in part to oxalic acid. I was unable to get a test for free oxalic acid from a solution obtained by boiling the leaves vigorously in water, but on treatment in like manner with hydrochloric acid a faint test for oxalate was obtained. As previously mentioned the ether, alcohol and water extracts all gave an acid reaction, but from none of these could any crystaline substance be obtained by concentrating on the water bath. Fermentation goes on very rapidly when particles of the leaf are steeped with about twice their weight of water, and even in the leaf itself if evaporation of its moisture content is prevented. By boiling about 500 grams of the leaf in water, acidified with sulphuric acid, and subsequently evaporating this solution to a small volume, a fairly concentrated solution of the plant acid was obtained. This was placed in a separatory funnel and extracted several times with ether, the ether evaporated off and the residue taken up in water. The resulting solution has the following properties:

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[1] Loc. Cit.

1. Decolorizes potassium permanganate solution in the cold in acid, alkaline and neutral solution.
2. Bitter taste and strongly acid to litmus.
3. No visible color reaction with ferric chloride.
4. Acid is nonvolatile at boiling point of water. At this point it may be of interest to add that on placing 500 grams of the leaf in a copper retort and subjecting to destructive distillation, the distillate remained neutral until the retort reached 130° C., temperature at which lactic acid is decomposed.
5. Acid miscible with alcohol, ether and water.
6. In the fresh leaf this acidity increases on standing in water to a maximum and then decreases.

In addition to these tests a measured volume of fresh juice was titrated with N/5 potassim hydroxide and showed an acidity of 0.45 per cent. This neutralized solution was allowed to stand and after two days' time upon titration it showed an increase in acidity of 0.75 per cent, or a total acidity of 1.10 per cent. This procedure was continued for eight days, at which time the solution reached a maximum acidity. These properties indicated the identity of the acid as being lactic acid, and in view of this fact the above tests were repeated on leaves obtained from plants grown on the Experiment Station Grounds, the juice of which was extracted as soon after cutting as possible. In this manner was eliminated the possibility of lactic acids being formed by lactic fermentation, which is known to take place in silage, etc.

A sample of the acid thus obtained, when subjected to Uffelman's[1] test for lactic acid, gave a decidedly positive reaction. In view of the further fact that this reagent has recently been found to also react with oxalic, citric, tartaric and succinic acids,[2] these acids were all carefully tested for with negative results. Another test for lactic acid, recommended by Georges Deniges,[3] namely, treatment with concentrated sulphuric acid and an alcoholic solution of guaiacol, gave a positive reaction. In this method the sulphuric acid converts the lactic acid into acetaldehyde, the presence of which is detected by means of the guaiacol.

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[1] Zeit, klin. Med. VII, p. 392.
[2] Abs. in E. S. R., Vol. XXIII, p. 115.

Following these tests a portion of the acid was subjected to an analysis by the Palm method.[4] In this analysis the per cent of $\mathrm{Pb\,O}$ obtained by incinerating the lead lactate, $\mathrm{3Pb\,O2\,(C3\,H6\,O3)}$, was found to be 78.36 and 78.07 per cent in two precipitations. The theoretical per cent is 78.50. Crystals were also obtained by treatment with zinc oxide which resembled zinc lactate crystals under the microscope, but no chemical analyses were made of these crystals to positively identify them as such. The above results were considered sufficient to warrant the conclusion that the acidity of the sisal leaf is due in most part to lactic acid.

Soon after the completion of this work the Fiber Company placed a new mill in operation at Robinson, Oahu, where the new plantation is located. They immediately noticed that the juice from the leaves did not attack the machinery so vigorously nor the hands of the laborers. Also that the decortication could be carried out without the addition of water, which is undoubtedly due to the fact that the leaves in this district contain 5 to 10 per cent more moisture than those from Sisal.

Leaves were sent to the laboratory from the two districts and the acid content was determined, with the result that those from Robinson showed the higher acid content. However, these leaves were younger and shorter in length, and would necessarily show a higher acid content than the older leaves, as has been proven in our investigation and which is shown in the following table:

TABLE COMPARING LENGTH OF LEAF WITH ACID CONTENT.

	1	2	3	4
Length of Leaf......	29 inches	38 inches	48 inches	50 inches
Acidity	.53 per cent	.51 per cent	.36 per cent	.27 per cent

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3. Abs. Jour. Chem. Soc., London, Vol. XCVI, pt. II, p. 627.
4 Jour. Amer. Chem. Soc., Vol. IX, p. 16; also Vol. XXXI, p. 1365.

Numbers 1, 2 and 3 are leaves from Robinson and 4 is from Sisal, and from the data at hand I do not believe there is any radical variation in acid content between leaves of the same length from the two districts. However, it has been noticed that the juice from leaves grown on the coral soil ferment much faster in the laboratory. After neutralizing the acid in the juice from 40 grams of the leaves, the whole was allowed to stand over night and titration repeated, with the result that the leaves from coral soil showed an increase of 0.31 per cent, while the leaves from Robinson had increased only 0.14 per cent. This may possibly be due to the higher lime content of the former, since lactic fermentation takes place more readily in presence of lime, and may offer some explanation as to why the machinery is attacked more vigorously at the Sisal mill.

The fact that the shorter leaves showed a higher acid content than the longer ones led the author to investigate the cause of this variation, since the only difference lies in the fact that the stump end of the leaf is much larger in proportion than in the smaller leaf and consequently contains more juice. A leaf, four feet long, was taken and cut into four lengths, each one foot long, and the acid content of each length determined with the following results:

TABLE SHOWING VARIATION IN ACID.

	1	2	3	4
Per Cent Acid	0.64	0.61	0.34	0.15

The samples are numbered beginning with the tip, which is No. 1, and ending with No. 4, which is the one-foot length nearest the stump of the plant. These results offer an explanation as to why the younger leaves contain the higher acid content.

INDUSTRIAL ALCOHOL FROM SISAL WASTE.

The analyses for carbohydrate content were made primarily with the idea in view of ascertaining its profitableness for making industrial alcohol. M. D'Herelle[5] considers that the *Agave rigida*

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[5] Loc. Cit.

Var. Sisalana of Yucatan can be used profitably for the production of alcohol and that other varieties of agave may also be used with just as good results, in consideration of the fact that the raw material is free from cost. He considers the industrial maximum as being 16 litres per 1,000 leaves and the average as being 13 litres per 1,000 leaves. With the daily working of 175,000 leaves in Yucatan they would obtain about 575 gallons of 95 per cent alcohol per day. With this large quantity of juice to work on and having overcome the difficulties to be encountered in fermenting sisal waste, the industry may be profitable enough to pay for the chemist or bacteriologist necessary for the supervision of the plant, thus forming a remunerative industry. In his article he cautions others as to the difficulties of the fermentation of sisal waste, and states that after trying a number of species of yeasts obtained from the Pasteur Institute, he finally provoked a successful fermentation with a special kind of yeast, the identity of which he does not divulge. Other experimenters[1] have not been so successful.

In view of the comparatively small quantity of waste accruing at present at the Hawaii plantations and the very low sugar content of sisal leaves, it is not deemed a profitable undertaking to utilize the sisal waste of Hawaii for making alcohol, taking into consideration the difficulties to be overcome in the fermentation. Several fermentations were made by the author in this laboratory, and while an alcoholic fermentation was obtained by using ordinary compressed yeast, the yield was very poor and indicated the difficulties to be overcome. In one instance an alcoholic fermentation was obtained by simply adding an excess of calcium carbonate and then allowing to ferment by mere exposure to the air, the calcium carbonate combining with the lactic acid as it is formed, thus checking the lactic fermentation.

In our analyses the sugar content of the fresh leaf varied from 2 to 7 per cent, making an average of 4.5 per cent,[2] which theoreticaly would yield about 26 litres (or 6.5 gallons) absolute alcohol per ton of leaves. It is hardly conceivable that with such a sugar content this could be made a remunerative industry with the waste at hand, and even with the large quantities of waste in Yucatan it would require a rather efficient system. The actual recovery of the juice, which is only about 50 per cent of that in the waste, and the services of a man trained in fermentation industries and familiar with the properties of sisal waste are two important factors to be considered before undertaking the manufacture of industrial alcohol from the sisal waste.

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[1] Bul. No. 25, Sta. Agron. Colony of Mauritius.

[2] These samples being taken from different parts of the island and grown under varying conditions, give a fair average of the sugar content of Hawaiian sisal.

For comparison it may be of interest to show the carbohydrate content of other fermentable substances along with sisal leaves:

CARBOHYDRATE CONTENT OF SOME FERMENTABLE SUBSTANCES.[1]

Corn	70	per cent
Potatoes	20	" "
Cassava	30 - 40	" "
Sweet Potatoes	20 - 25	" "
Bananas	20	" "
Cactus	7 - 20	" "
Sisal (our analysis)	2 - 7	" "

Herbert and Heim,[2] after working on sisal waste, concluded that while the fermentation of sisal waste for alcohol deserves consideration, the obvious and immediate application of this waste is to return it to the land in the form of manure.

CHARACTER OF THE MINERAL CONTENT.

From a previous table, showing the analyses of the leaves, it may be seen that there is considerable variation in ash content, namely from 8.53 per cent to 14.76 per cent on the moisture free material. This ash content is rather high in comparison to the most plants, and indicates the extent to which the sisal plant draws upon the soil for its mineral plant food. At this point will be given a table showing analyses of the ash obtained by burning leaves taken from various sources and growing under varying soil and climatical conditions.

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[1] Bul. 130, Bur. of Chem. U. S. Dept. of Chem.
[2] Compt. Rend. 1909, 148, pp. 513-514.

CHEMICAL COMPOSITION OF ASH.

	1	2	3	4	5	6
	Per Cent	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*	*Per Cent*
Silica ($Si O_2$)	.46	.84	.42	1.06	.74	.30
Ferric oxide ($Fe_2 O_3$.......	1.18	.44	1.68	.51	.36	1.32
Aluminum oxide ($Al_2 O_3$)	4.86	3.80	4.04	4.40	5.66	4.74
Manganese oxide ($Mn_3 O_4$)	0.08	0.05	0.14	0.17	0.00	0.28
Lime ($Ca O$)	20.88	21.58	45.68	22.84	45.44	21.56
Magnesia ($Mg O$)...........	10.44	22.00	8.48	26.60	5.24	24.56
Potash ($K_2 O$)...............	20.64	12.00	10.08	14.68	10.64	17.80
Soda ($Na_2 O$)................	5.68	10.12	3.68	1.96	5.24	6.44
Sulphur Trioxide ($S O_3$)....	2.88	2.64	3.12	2.56	2.56	1.60
Phosphoric Acid ($P_2 O_5$)...	1.54	8.57	3.50	9.76	4.40	6.24
Chlorine (Cl)	....	.35	....	.22	....	....
Carbon dioxide ($C O_2$)	31.36	17.61	19.18	15.24	19.72	15.16

The columns are numbered in agreement with the leaves, the analyses of which are reported in the table on page 12; i. e., column 1 is the analysis of the ash obtained from the ignition of the leaf whose analysis is shown in column 1, page 12. From these results it is clearly evident that the plant feeds most heavily upon phosphates, lime, magnesia, potash and soda, and since nearly all this mineral matter remains in the waste the analyses strongly indicate the advisability of returning the waste to the soil as fertilizer. Without this precaution the necessity of the application of artificial fertilizer to obtain best results is apparent.

From these results it may also be seen that there is a striking variation in the amounts of the minerals on which it feeds most heavily. Phosphoric acid in every instance was highest in those plants grown on the Station Grounds, varying from 6.24 to 9.76 per cent in the ash. The next highest were the plants grown at Sisal, Oahu, while the lowest, 1.54 per cent, was grown at Robinson, Oahu. The soil at the latter location is of the heavy, red clay type, the phosphoric acid content of which is known to be held in a difficultly available form as ferric or titanic phosphates. This fact indicates that better results could be obtained by applying small quantities of phosphoric acid in a more available form. The fact that the plants grown on the coral soil contain more phosphoric acid is probably due to its being in a more available form than that in the heavy clay soil, namely, in combination with the lime. The character of the soil on which the plants are growing at the Experiment Station is a fairly loose soil, formed partly by the disintegration of the black volcanic ashes which make up the subsoil.

Similarly the lime content varies greatly according to environment, being of course highest in those plants grown on coral but showing little variation in the plants grown on the other soils. There is a rather striking relationship between the lime and magnesia contents of all the plants, namely a high percentage of lime correlating with a low per cent of magnesia and vice versa, and is apparently not accompanied by any noticeable injury to the plants. Those grown on the coral soil contain more than twice as much lime as the other plants, and considerably less magnesia in spite of the fact that Hawaiian corals contain from 0.11 per cent to 9.95 per cent magnesia.[1] It may be of interest in this connection to call attention to the magnesia content of the ash of plants grown at the station grounds and those at Robinson, Oahu, where the lime and magnesia content of the soils is as follows:

	Station	Robinson
	Per Cent	*Per Cent*
Lime	0.28	0.62
Magnesia	6.25	0.36

These results tend to indicate that the sisal plant when grown in an abundance of lime, will assimilate it in largest quantities but in normal soils will thrive just as well on smaller amounts of lime, replacing same with magnesia and in small part with potash as may be seen by reference to the table of ash analyses. The potash seems to be governed by the lime content but not nearly so strikingly as the magnesia. Manganese apparently has no injurious effect upon the sisal plant. The plantation at Robinson is situated in the district in which the highly magniferous soils occur and the sisal plant is thriving and shows no deleterious effects from the manganese.

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[1] U. S. Geological Survey, Bul. 419, p. 210.

CONCLUSIONS.

1. Obviously the best utilization of the waste is to return it to the soil, for unless such is done the soil will in time tend to become exhausted. By using this waste as fertilizer all the mineral matter will be returned to the soil except that in the fiber, which will compensate for the most of the plant food removed from the soil by the plant.

2. The use of sisal waste as a stock feed has been fairly successful in other countries, when fed in the fresh form. I do not think it has ever been fed as a dry feed, but believe such a use to be fully deserving as a trial, not alone but mixed with other rations. When properly dried it contains a fairly high percentage of sugars from which it derives its nutritive value and should give good results along with other feeds.

3. The utilization of this waste for making alcohol is claimed by M. F. D'Herelle to be a remunerative industry in Yucatan. At present outlook I do not believe this means of utilization could produce promising results in Hawaii.

4. As for the lactic acid content, I do not consider that it could possibly be of any commercial value.

Acknowledgments are due Miss Alice R. Thompson for valuable suggestions offered from time to time and to the Hawaiian Fiber Company for their co-operation.

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Hawaii Agricultural Experiment Station,

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN No. 36.

THE PINEAPPLE IN HAWAII.

BY

J. E. HIGGINS,

HORTICULTURIST.

INTRODUCTION.

Pineapple growing is a new industry in Hawaii. It is only a few years ago that its foundations were laid, and less than a decade since any rapid development began. As is often the case with new enterprises, it was the subject of scorn and ridicule, and land which now smiles with its golden harvest of fruit was said to be useless for any purpose except the grazing of a few cattle. The industry is now well established, and although there are many unsolved problems connected with the growing and marketing of the crop, the experimental stage is well past and the attention of homesteaders and capitalists is being attracted to this new field. With the recent opening of Government lands in various parts of the pineapple belt for homesteading, has come a demand for information relative to methods of growing pineapples in Hawaii. This station has published several bulletins dealing with special phases of the subject, such as the management of pineapple soils,[1] the manganese problem,[2] the pineapple scale,[3] and the marketing of the fresh fruit on the mainland,[4] but no publication covering the field in general has been issued. This paper is presented as an attempt to bring together in a simple way the results of experience on the more important aspects of pineapple cultivation in Hawaii, but while general in its scope it makes no attempt at an exhaustive treatment.

SOILS.

The pineapple is not exacting as to soils. Flourishing plantations may be found in Florida on the lightest of sandy soils, while in Hawaii broad fields may be found upon very heavy soils subtended by a still heavier stratum. Good drainage is an absolute necessity. In the pineapple belt of these islands, on the areas which have up to the present time been occupied by pineapples, there are three general types of soils, including the red soils, the chocolate brown or shotty soils and the black soils. Opinions are divided as to the relative merits of the red and chocolate types. The black soils, which are perhaps the most attractive in appearance of any soils in the islands, have been found to be the least desirable for pineapple cultivation, because of the very high content of manganese, which acts as a poison to the plants. Soils containing more than 1 per cent of manganese are regarded as unfit for pineapple culture at present. This subject of manganiferous soils and the whole subject of pineapple soils in Hawaii has been discussed in Press Bulletins Nos. 23 and 29 and Bulletin No. 26 of this Station, and those who wish to look into the subject more in detail are referred to these publications, which may be had on application to the station.

LOCATION OF PLANTATION.

Pineapples are found prospering in Hawaii from sea level to elevations of about 1,200 feet or more. The usual pineapple belt lies just above the cane area, but on lands not sufficiently watered for cane the pineapples extend to the lower levels. The

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[1] Press Bulletin No. 29.
[2] Press Bulletin No. 23; Bulletin No. 26.
[3] Press Bulletin No. 10.
[4] Bulletin No. 14 and Press Bulletins Nos. 21 and 22.

EXCHANGE
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moisture requirements of the pineapple are supplied by a rainfall of about 50 inches per year, if this is reasonably distributed throughout the twelve months, but a very large precipitation does not appear to be injurious to the plants provided the drainage is perfect. In the district of Hilo, on the Island of Hawaii, pineapples prosper where the rainfall sometimes exceeds 12 feet per year. Standing water will not be endured, and flooding for even a short time is likely to ruin the crop. For these reasons land having a reasonable slope is generally preferred to that which lies nearly level. The facilities for transportation must of course be carefully considered in locating the plantation. A large crop can not be economically transported any great distance without a railroad outlet to some port where ocean steamers call.

PROPAGATION.

Except for the purpose of breeding new varieties, the pineapple is always propagated by parts analogous to cuttings. Of these there are four different kinds, arising from different parts of the plant. They are known as suckers, crowns, slips and stumps.

Suckers. Suckers are young shoots arising from buds in the axils of the leaves (figs. 1 and 4). They produce fruit more quickly than any other kind of plant and are very extensively used. Their fruiting, however, is not quite so uniform in time as the fruiting of plants grown from crowns. These suckers are taken from the plant shortly after the fruit has been gathered. After this time they mature rapidly, but must not be allowed to remain too long upon the plants, because they will become too far advanced and the processes which are to form the flower bud will already have been set up and will result in the bearing of a premature fruit which is likely to be worthless. Just the proper stage of maturity for removing suckers from the mother plant is difficult to describe and must be learned by experience and observation. The leaves lose their fresh green color, which is characteristic of the immature suckers, and become slightly redened and also spread out a little. If taken at the right degree of maturity these suckers may produce pineapples in from 15 to 18 months. This is a shorter period than is required for crowns at any season.

Crowns. The crown is the tuft of leaves at the top of the

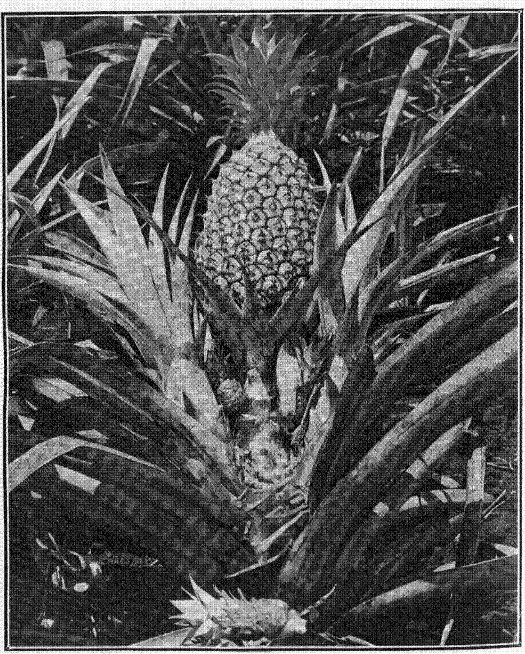

Fig. 1. Plant of the "Queensland" variety from which one side has been partly cut away, showing two suckers arising from the axils of the leaves on the stem of the plant, also two slips attached to the stem of the fruit. One slip has been removed and lies at the base of the plant.

fruit (fig. 1). If the fruits are sold as fresh fruit the crowns must remain on them and so can not be used for planting. If the fruit is canned the crowns become available as a future plant. Fields planted with crowns do not mature their fruits so rapidly as suckers. It requires nearly two years to get fruit from such plants. The fruits, however, will come on more uniformly, nearly all of the field fruiting at nearly the same time, while the fruits from suckers may come on partly as a summer crop and partly in winter.

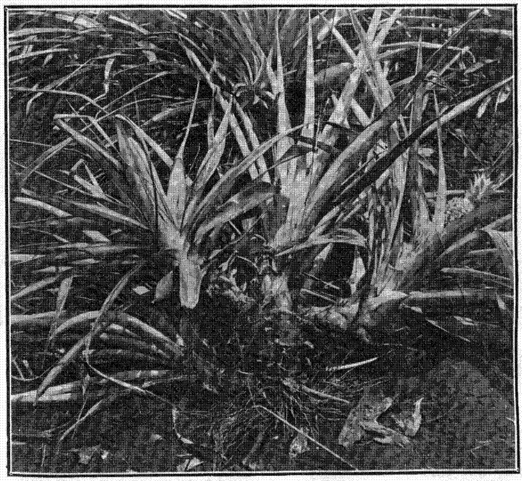

Fig. 2. An uprooted plant, showing four ratoon suckers. One of these has been quite deep in the soil, while two have started just beneath the surface and the fourth or central sucker is a little higher. In front of the latter may be seen the shrivelled leaves and old stem from which the first fruit was cut.

Slips. The small shoots attached to the sides of the stem of the pineapple fruit are called slips (figs. 1 and 4) . These are regarded as good plants, maturing probably a little more slowly than a sucker crop. They are allowed to remain on the mother plant rather longer than suckers after the fruit is gathered, since they do not grow to large size while the fruit is still drawing its sustenance from the plant.

Stumps. The stump is the base of the old plant, a part of which is in the ground and a part above ground. These are now used less than formerly, when suckers were more difficult to secure than at present. On good pineapple land their chief use is in making a nursery from which to draw a supply of new plants which will be taken up and set in other fields. Part of the shoots which they send up may be allowed to remain to form fruit. In soils which contain rather excessive amounts of manganese, stumps are probably the best plants to use. The young plants, feeding upon the stored up food material in the stump, do not appear to suffer so much from manganese poisoning as do plants which must depend upon their own root system for sustenance from the beginning. The number of plants which may be secured from a stump depends upon whether it is young and upon the treatment which it receives. If allowed to get old and dry, few buds will start. If planted while still young and vigorous and if well supplied with moisture, as many as ten or eleven plants per stump have been found. In ordinary practice not more than three or four should be expected. These stumps are planted in a continuous line in a furrow and covered with about three inches of soil. (figs. 2 and 3).

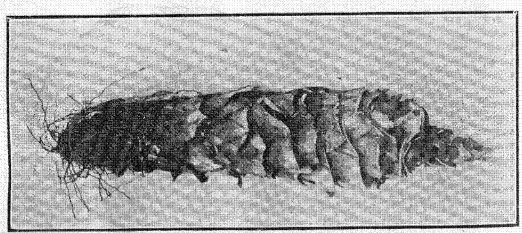

Fig. 3. A stump pruned and ready for planting.

Preparation of the Plants. Suckers, crowns and slips are prepared for planting by removing a few of the leaves at the base and cutting off the end. Figure 4 shows a sucker, a crown and a slip prepared for planting. Some experience is necessary to determine how many leaves should be removed. If too many are taken off the tissue exposed is very tender and is liable to decay. Suckers sometimes require trimming on the top also, or rather the trimming of the side leaves. If left too large they are liable to be blown out of the ground by the wind. Crowns are commonly so much spread out that cutting back some of the side leaves, as shown in the illustration, may be necessary in order to get them sufficiently into the soil. All plants so prepared are generally allowed to lie in the sun for a few days until their cut surfaces are dried. They are thus less subject to decay. The removing of a sucker from the mother plant requires some experience. They hold on rather tenaciously, and an inexperienced hand may break them in getting them off. The leaf just subtending the sucker is usually cut off, and then it is not difficult to press down upon the sucker and break it off, after it has been moved about a little in several directions.

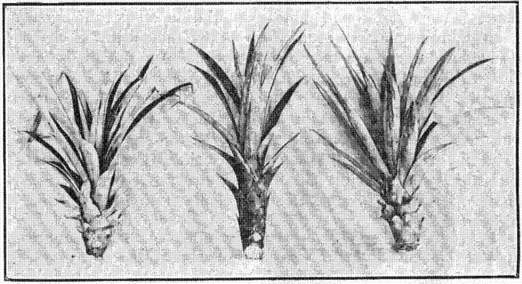

Fig. 4. A sucker (in centre) and two slips. The slip on the right has been cut, stripped and pruned in the usual manner for planting.

Selection of Plants. Of course only healthy plants should be selected as a source of supply for new plantings. To what degree certain peculiarities of form in the pineapple are inherited is not known. For example, quite a number of fruits may be found in most fields producing multiple crowns. These crowns may be only two or three in number, or may spread over the whole of the fruit, making a large, deformed, fan-shaped top to the fruit, greatly increasing the amount of core, and in extreme cases rendering the fruit useless for marketing. Whether these plants tend to transmit such peculiar characteristics to their offspring is not known, although good results have sometimes been reported from the use of such stock. The same question arises in regard to plants which produce fruit of any particular shape. Fruits are found quite cylindrial in shape and almost as large three-quarters of an inch below the crown as at the base, while others are tapering in form. The former is very much to be desired, because it is more economical for canning purposes. Fruit tapering to a point may be much larger than is necessary to form a standard sized slice from the base of the fruit, but several slices at the top may be too small. Some experiments are now in progress to determine whether this characteristic is inherited or not. If they are proved to be transmissible, it will be possible to select plants from those of desirable form.

PREPARATION OF THE SOIL.

Most land on which pineapples are planted in these islands is either virgin or has been in pineapples previously. There are few instances where pineapples are planted on soil which has been occupied by other crops, except where some quick crop, such as watermelon, has been used as a means of preparing the soil for pineapples. Either virgin soil or that which has been in pineapples will require very thorough preparation. In the case of virgin soil it is customary to plow about 4 or 5 inches deep with an ordinary moldboard plow. This is followed by harrowing about once per month for a period of 5 or 6 months. Either spike tooth or disc implements are used. The soil is then plowed as deeply as possible, and with disc plows running at right angles to the furrows of the first plowing if possible. It is necessary to thus prepare land deeply in order to make a deep reservoir for the conservation of moisture, and also to make it possible for the water to get away from the soil which is to be occupied by the pineapple roots. Steam plowing has been practiced to a limited extent, but is not generally used. It is quite possible that where steam plows are readily available and the subsoil tenacious, it would pay to use this means of breaking the soil deeply. This second deep plowing is followed immediately by harrowing with disc implements until the soil is in thoroughly good tilth. It thus requires about six months to properly prepare the soil.

Soils that have been in pineapples for four or five years usually require quite as much, or even more, preparation than the virgin soils, because of the hardened condition which the subsoil has acquired during the years of constant surface tillage. Not a little difficulty was experienced in the early years of pineapple growing in these islands by making the second planting upon soil insufficiently prepared, and this led to the belief by some that the pineapple was exhausting upon the soil and that probably not more than one planting could be made. Experience has taught that this idea is not well founded, and it has been well known for many years that the pineapple plant is not extremely taxing on the soil. Thorough preparation and spring planting appear to solve the difficulty. Just what methods are best to use in breaking up the subsoil, and thus giving an opportunity for the aeration of the soil and the percolation of water, is not yet a settled question. Experiments, under the personal supervision of the Director of this Station, are now in progress to determine the effect and economy of the use of a special brand of giant powder. In these experiments a drill was driven into the ground, making a hole about three feet deep. Into this one stick of the powder was placed and the soil thoroughly tamped over it. Such holes were made about 8 feet apart throughout the field and the charges set off in succession. The explosion jars the lower strata of soil, but does not disturb the surface to any great extent. The cost is about $20 per acre. What the results will be, measured by the success of the future crop, it is too early to state, but the indications are good from the condition of the soil after blasting.

If the soil is virgin it has been found a very good practice to get a short crop from it during the 5 or 6 months of preparation. Watermelons have been successfully used by some planters and with good profit. The success of this crop depends upon being within reasonable reach of a good market and upon the ability to control the melon fly. This fly is usually not a very serious menace to the first crop planted upon virgin soil at some distance from other plantings of vegetables which are subject to the attack of the fly. It is quite probable that some cover crop will be necessary between the first and second or later plantings. Cover crops have been used to a limited extent for this purpose. They serve to penetrate to the lower depths of the soil, and when plowed under add much humus, and, if legumes, they also increase the nitrogen supply. The crops which are recommended for further trial are the pigeon pea, jack bean, cow pea, soy bean, lablab bean, and the like.

PLANTING.

Distance and Arrangement. There are many plans for the arrangement of the plants in the field. A type of one of the most common methods is illustrated in figure 5, a. This consists in placing all the rows equally distant apart, in this case about 48 inches. The plants in a row are placed 20 inches apart. The number of plants on an acre set in this manner and allowing for driveways is between 5,000 and 6,000. A second plan is illustrated at b in figure 5. Under this arrangement the rows are at equal distance. They are about 36 inches apart and the plants in the row about 15 inches apart. Under this system, allowing for crossroads, approximately 10,000 plants are placed upon an acre. This method is somewhat extensively used in certain parts of the islands with great success, but in much of the pineapple area it is claimed to be impractical. The advantages claimed for the system where it can be practiced are obviously that about twice as many plants are placed upon an acre, meaning a much larger yield, and further that the fruits approach more nearly to the desired size for canning purposes on the "plant crop," as the first crop after planting is called. With very wide planting a considerable proportion of the first crop runs to so large a size that there is loss in sizing down to the dimensions of the can. This is not wasted, now that so many secondary products are being put out, such as crushed, grated and shredded fruit and pineapple juice, yet the highest priced article is the large size slice. Those who advocate this system of planting also defend it with the claim that the plants soon cover and shade the greater part of the ground, thus eliminating much hand hoeing. The third plan illustrated (fig. 5, C.)

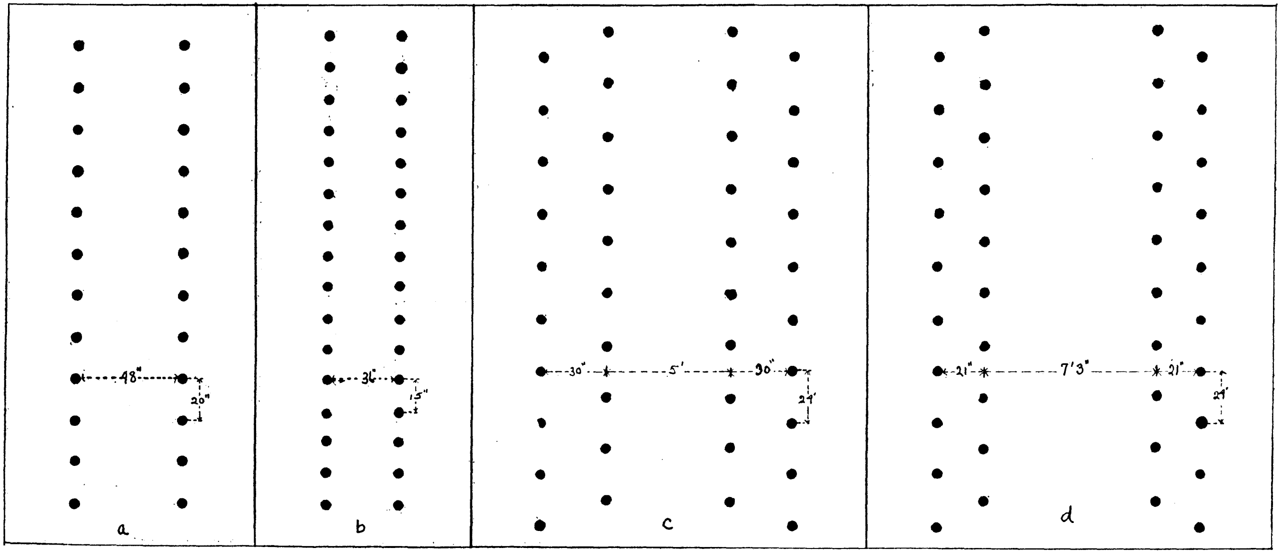

Fig. 5. Planting Plans Common in Hawaii.

provides for the setting of double rows. The plants in the row stand 24 inches apart and two rows are 30 inches apart. Then comes a space of 5 feet, followed by another double row. This plan gives about 5,000 plants per acre after allowing for land used in crossroads. This has proved one of the most popular methods of planting. It permits of the use of cultivators throughout the entire time that the plants are standing upon the soil. The plants being rather close together, support each other more or less, as they do in close planting. A fourth plan (fig. 5, d) places the plants about the same distance in the row, but makes the two parts of the double row stand closer together and leaves a wider space for the tillage by horse-drawn implements between the double rows. The plants stand about 24 inches apart in the row and the next adjoining row is 21 inches distant, the plants in the latter being placed opposite the space in the first row, or on what is called the quincunx plan. Then follows a space of seven feet three inches before the next double row, and so on throughout the field. This system has not been widely used. The claim made for it is that it permits of the use of disc implements drawn by two mules throughout the entire time that the plants are occupying the soil, and by thus ridging the soil about the plants two or even three ratoons may be taken. This system also accommodates about 5,000 plants per acre. Occasionally the plants are set in beds of three rows, quite close together, with a space wide enough for a cultivator between the beds.

Seasons for Planting. The limits of the season for planting may be said to be from April 1st to November 1st, and preferably in most years from May 1st to October 1st. Planting suckers in the spring and early summer is likely to produce a more quickly maturing crop, usually not so good as obtained from late summer or early autumn planting.

Preparing the Rows. To prepare the rows for planting, a small plow is run twice through the same furrow, throwing the soil in opposite directions. This is usually followed by a cultivator passing through the row. If fertilizer is to be applied at planting time, it may be placed in the row before the cultivator passes through. A planting line is then run up and down the row. This line is specially prepared, according to the system of planting which is to be followed. It is usually made of ordinary clothes-line wire in which brass rivets have been placed at the same distances at which the plants are to stand. Any unevenness in the furrow is corrected by the use of mattocks and hoes, so that the plants can be set with accuracy in a straight line. A man passes along the row, distributing the plants as he goes, and is followed by the planters.

Placing in the Soil. The plants are pushed down into the mellow soil which is slightly pressed about them, one plant being set at each rivet in the line. The depth at which they are planted depends in part upon the plant itself and in part upon seasonal and soil conditions. Crowns can not be inserted more than about one and one-half inches in the soil. Suckers can be placed deeper, and in warm weather when the soil is not too wet they are placed three or four inches in the soil. In wet weather it is not safe to plant them so deeply.

Ridge and Level Planting. The method which has just been described leaves the ground nearly level when the planting operation is over. In rather heavy soils not perfectly drained there would be an advantage in putting the plants upon a slight ridge. This has been practiced to a limited extent. The difficulty with such a plan arises when the ratoon crop is in progress. It then becomes very difficult to get the soil up about the new shoots which are bearing this second crop, and failing in this there is danger of the plants breaking off. In a thoroughly drained, porous soil, placing the plants in a depression gives an excellent opportunity to get the ratoon suckers well rooted in the soil which can easily be worked toward them.

TILLAGE.

Tillage by horse-drawn implements is practiced in all wide planting systems and for a shorter time with the close planting plans. The implements used are chiefly the ordinary one-horse cultivator, but, as indicated above, two-horse implements are also in use. One grower reports excellent results from the use of an implement which strides the rows, so that the cutting parts work up quite close to the stump of the plant under the leaves without seriously injuring them. A man with one mule and the ordinary cultivator is expected to cover from 60 to 70 acres in pineapples. Cultivation is repeated about once every three or four weeks. It is important to consider the condition of the soil when horse tillage is to be practiced. There can be little doubt that much injury is done by the constant tramping up and down the rows when only a few inches on the surface are in suitable condition for cultivation while the whole soil below is too wet and is packed tightly by the very process which loosens the surface soil. It will be understood that this does not in any way discourage the liberal use of the cultivator or other horse-drawn implements, but merely emphasizes the need of delaying its use until the soil becomes sufficiently dry beneath. Hand hoeing is practiced in practically all methods of planting, since no attempt is made to cultivate by horse power in two directions. Under most methods of planting a good laborer should do the hand work that is necessary on about 30 acres of land.

REMOVAL OF CROWNS.

A few growers remove the crowns from young, developing pineapples, believing that this causes the upper end of the fruit to "fill out" more and thus make a better fruit for the cannery. This has not become a general practice, and there is much room for doubt as to whether it really increases the weight of fruit available for slices. It gives the pineapple the appearance of being more developed at the top, but about three-fourths of an inch of the upper end is always eliminated and it has yet to be proved that the pineapple below this point is of any greater diameter because of having its crown removed. If new plants are in demand, the removal of the crown means the loss of a plant, and a pineapple without a crown cannot be used in fresh fruit shipping.

GATHERING THE CROP.

Seasons of Maturity. The pineapple appears to have a decided inclination to fruit during the summer season. Another season of lighter crop comes in the winter. The months of July and August are the most important ones for the gathering of the crop, and a large percentage of the fruits must be handled during a period of two or three weeks. There are, however, ripening pineapples here and there in the fields throughout the entire year. It has been found possible to control the seasons of maturity to only a limited degree. For example, if suckers are planted about April 1st at Wahiawa, it is quite likely that the crop of fruit will be produced in one year from the following summer; that is to say, in sixteen or eighteen months from the time of planting. Suckers set about June 1st are very likely to flower during the autumn flowering season and mature a considerable crop during December and January, about 19 to 20 months from planting. This appears to be about the best time to plant in that locality for a winter crop. At this time, however, plants are not as easy to secure as later in the season, since both suckers and slips mature chiefly after the fruits have been removed. If the planting is delayed until the first of July, the next flowering season, which for the winter crop will be in the autumn, will not find these plants sufficiently matured to produce flowers, and as a result they will pass over to the next spring and will mature their first crop of fruit in June and July, about two years from the time of planting. The accompanying table will serve to show in a general way the probable time for the maturity of crops from plantings at different times during the planting season at Wahiawa. Of course, seasons differ and the table must be regarded only as approximating the probable outcome.

Gathering Fruit for the Cannery. The fruits required by the canneries for their best grades of canned product weigh from 3½ pounds upward. For such the highest prices are paid, and anything running under this standard must usually be sold at half price. Most canners prefer fruit running about four pounds. The fruit should be as nearly cylindrical as possible, as indicated elsewhere in this paper, in order to supply as many slices as possible from each fruit. Pines for canning are gathered when they are quite ripe, but many of the fruits are taken before they have lost all traces of green color. If, however, only a trace or two of green on one side of the upper portion of the fruit is to be found, the flavor of the fruit as a whole is about perfect.

Care should be taken in handling the fruits so that they will not become bruised on the way to the cannery. Fruits for canning may be broken from the plant and need not be cut, as is necessary for fresh fruit shipping. They are carried out to the ends of the rows and placed in piles on the driveways. Here

Approximate seasons of maturity at WAHIAWA.

Time of Planting 1912	Mar. 31, 1913	Apr. 30 "	May 31 "	June 30 "	July 31 "	Aug. 31 "	Sept. 30 "	Oct. 31 "	Nov. 30 "	Dec. 31 "	Jan. 31, 1914	Feb. 31 "	Mar. 28 "	Apr. 30 "	May 31 "	June 30 "	July 31 "	Aug. 31 "	Sept. 30 "	Oct. 31 "	Nov. 30 "	Dec. 31 "	Jan. 31, 1915	Feb. 28 "	Mar. 31 "	April 30 "	May 31 "	June 31 "	July 31 "	Aug. 31 "	Sept. 30 "
April 1	12	13	14	15	16	17	18	......	......	21	22	......	......	......	......	......	28	29	......	......	......	......	......	......	......	......	......	......	......	......	......
					Main crop					Part crop							Ratoon														
May 1.........	......	12	13	14	15	16	17	18	19	20	21	......	......	......	......	......	......	......	......	......	31	32	33	......	......	......	......	......	......	......	......
						Part crop			Main crop												Ratoon										
June 1	......	......	12	13	14	15	16	17	18	19	20	......	......	......	......	......	......	......	......	......	30	31	32	......	......	......	......	......	......	......	......
							Part crop			Main crop											Ratoon										
July 1	......	......	......	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	......	......	......	......	......	......	......	......	......	......	37	38	39
													Part crop			Main crop													R ı		
Aug. 1........	......	......	......	......	12	13	14	15	16	17	18	19	20	21	22	23	24	25	......	......	......	......	......	......	......	......	......	......	36	37	38
															Part crop		Main crop												Ratoon		
Sept. 1........	......	......	......	......	......	12	13	14	15	16	17	18	19	20	21	22	23	24	25	......	......	......	......	......	......	......	......	......	35	36	37
																	Main crop												Ratoon		
Oct. 1........	......	......	......	......	......	......	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	......	......	......	......	......	34	35	36
																	Main crop					Part crop							Ratoon		

Consecutive figures indicate the number of months from planting to harvest.

they are laid into lug-boxes built expressly for this purpose. These boxes measure about 13″x16″x22″ and must be strong. They are frequently reinforced by wire bands, such as are frequently used to strengthen packing cases. These lug-boxes after being filled are placed upon the wagons and carried either to the cannery or to the railroad siding. If to the latter, they are placed upon flat cars with racks built expressly for this purpose and are taken immediately to the cannery. It is desirable to can the fruits the same day they are gathered or the day following.

RATOONING.

Reference has been made to the suckers which grow from the axils of the leaves. These may arise from below ground or higher up on the plant. (fig. 2.) Some of these are removed for new plantings, but two may be left to produce the next year's crop. This is spoken of as a "ratoon" crop, even though the sucker may arise from a point well above ground. Judgment should be used in selecting the suckers which are to be left for the next crop, leaving the lowest possible. If the soil can be kept about them, the support will be good and they will send out roots of their own, whereas a high sucker when heavily laden with fruit is liable to be broken off. Do not leave a sucker which will interfere with another on a neighboring plant. Usually two suckers are left on each plant for the ratoon crop, provided they are well placed.

Usually one plant crop and one ratoon are taken from a field, and good fields may yield a profitable second ratoon, or even a third, after which the field must be plowed up and replanted as described elsewhere.

FERTILIZERS FOR PINEAPPLES.

The Hawaiian pineapple industry being of recent development and having been carried on largely on virgin soils, very little systematic investigation of fertilizing has been pursued. The department of chemistry of this station conducted two extensive plot experiments with fertilizers. One of these was to determine whether any of the fertilizers would overcome the yellowing, stunted effects noticeable on the black soils. The report of this work[1] is "that the application of liberal amounts of various high grade fertilizers, in conjunction with good tillage, drainage, etc., has not resulted in overcoming the yellowing of pines on this land." The other series of experiments referred to was made upon red soil, but no reports of this work have been published.

Mr. Carlton C. James[2] has published a report of extended experiments with fertilizers on pines on virgin soil at Waimea, Oahu. Mr. James concludes from the results of these experiments that nitrogen is not the dominant element in pineapple fertilizing. Nitrate of soda seemed to have injurious effects, and if nitrogen should be required in any soils it would appear better to apply it in some organic form, such as hoofmeal, or in the form of sulphate of ammonia. On this soil, however, no form of nitrogen alone gave increase in the crop sufficient to pay for the fertilizer. It must not be forgotten, however, that the results might be different where pines have been grown on the land for many years.

As sources of phosphoric acid, which appeared to be a most important factor, superphosphate, reverted phosphate and steamed bonemeal showed good results. Superphosphate in particular gave very excellent results, greatly increasing the yield and the net profit. Its beneficial effects appeared to be increased on land treated with lime. It should be remembered, however, that lime must not be added to soils that approach the limit of safety in their manganese content.

Potash in the form of sulphate and of muriate showed good effects, but even better results followed the use of sulphate of potash magnesia.

MARKETING.

The subject of shipping and marketing Hawaiian pineapples has been discussed at length in three bulletins of this station[3] and need not be considered in detail in the present paper, since the earlier publications are available to all those who may be interested in the matter. Only a brief summary of the most important features of packing and shipping will be mentioned.

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[1] Hawaii Experiment Station, Press Bul. 23.

[2] "The Effect of Fertilizers on the Growth of Pineapples," by Carlton C. James, Hawaii Forester and Agriculturist, Vol. VIII, No. 5.

[3] Hawaii Expt. Sta. Bul. 14, and P. Buls. 21 and 22.

Care in handling is the first essential in the successful shipping of pineapples. This begins when the laborer places his hand upon the fruit to harvest it and must continue until it is delivered to the consumer. Select normal fruits from fields producing a healthy crop, free from the symptoms of manganese poisoning, manifested by reddish fruit and yellow leaves. Fruit for shipping without refrigeration must be cut quite green. In the summer time the stage of maturity generally regarded as best is indicated by the appearance of a light pea-green color about the "eyes" or segments of the fruit near its base. In the winter season they may be allowed to advance further on the plants and show a slight yellowing about the base.

The laborer cuts the stem with a knife, for it must not be broken as is done with ripe fruits for the cannery. The fruits are carried to the driveways at the ends of the rows and are there placed in lug-boxes. They may be left exposed to the sun for an hour or two and the effects will be beneficial. The spores of the Soft Rot fungus are destroyed by direct sunlight.[2] The fruits are then carried to the packing house, placed upon their crowns and allowed to cure. This consists in the elimination of excessive heat and the drying and shriveling of the stems, which takes place in about a day or more. A few stems are likely to fail to become dry, and these must not be shipped, since they are almost sure to decay.

CRATES AND PACKING.

The crates which have been used extensively in Hawaii measure 15 x 17 x 40", inside measurement, and will contain from 130 pounds to 150 pounds of pineapples. The heads and a portion through the center are made of about 7/8" material and the slats are 3/8" thick. This is rather a large package and various attempts have been made to devise a more satisfactory size. A very small crate, holding about five or six good sized fruits, has been used by one of the largest shippers for express shipments. A medium sized crate measuring 15½ x 16 x 22¼", inside measurement, appears to be one of the most suitable packages yet devised for freight shipments. It will be observed that it is of convenient size and has flattened edges. Practically no packing space is thus sacrificed, but the shape prevents the crates being placed so closely in the ship or car that no air can circulate among them.

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[2] Larsen, Expt. Sta., H. S. P. A., Pathological Series Bul. 10, p. 15.

For packing material excelsior only is being used at present. Hay made from wild grasses was much used formerly, but now will not pass the California quarantine regulations. The use of a paper wrapper for each fruit has not become at all general in Hawaii, but is to be recommended. The bottom of the crate is covered with excelsior. Each pine is wrapped with a layer of this material passing about the base and is then placed in the crate. The next fruit is placed in the opposite direction, with the crown close to the first fruit. When one layer of fruit is in the crate more excelsior is worked in about the pines and on top of them. The second layer is begun by placing a pine immediately over the crown of the first one in the tier below, and so alternating until the crate is full. An essential point in packing it to get the fruits closely nested together and tightly in place, so that when the slats are nailed down there will be no shifting of position within the package.

SHIPPING.

The fruit must be placed on the ship where it will be well ventilated, dry and reasonably cool, and it must be carefully handled. Because of inadequate facilities for ventilating the 'tween decks of the steamers, most shippers prefer to have their fruit on deck and covered with a tarpaulin. This should not rest closely upon the crates, but should be raised so as to give better ventilation and avoid heating. It is also important that the crates be raised slightly from the deck and that they be so placed that the air can pass freely among them.

VARIETIES.

It is commonly stated that there is but one variety of pineapple grown commercially in Hawaii. On the contrary, there appear to be at least two distinct varieties, and possibly several strains of the commoner of these, the Smooth Cayenne. Some of these differences attracted the attention of the writer, and selections were made in the summer of 1910 and the cuttings planted for comparative study. These will be maturing fruit during the 1912 season. A recent visit to the Island of Kauai, where the pineapple industry is of later development, revealed two varieties quite distinct in whole fields, the plants having been received from different plantations on Oahu or Hawaii. One of these is the Smooth Cayenne of the ordinary tpye, fig 6, centre of foreground. It is a stout, robust plant, quite free from disease as seen on the plantations of Kâuai. The fruit is produced upon a very short stem, which carries few slips and usually none. The fruits incline to be barrel-shaped, with an occasional specimen tending toward a conical form. They become well ripened within and the flesh is of good color, flavor and texture before the green color has entirely disappeared from the outside. These are spoken of on Kauai as the "Hilo" pineapple, since the original stock for their plantations is said to have come from that district.

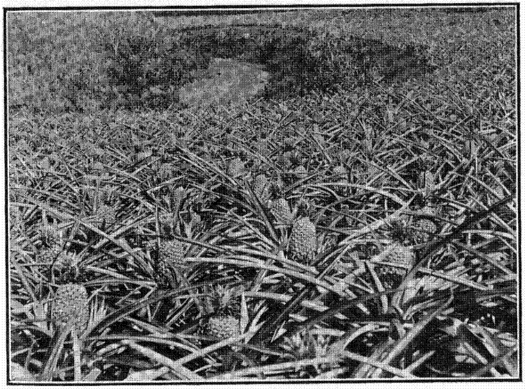

Fig. 6. A plant crop of the "Queensland" variety chiefly. Note the large cone-shaped fruits, standing high, above the leaves. A Smooth Cayenne occupies the centre of the foreground. Note how much lower it is among the leaves, the absence of slips and the barrel-shaped fruit.

Another variety is found of taller growth, but not more vigorous, (figs. 1, 6, 7.) The fruit is larger in size than the Cayenne, with a decided tendency to the conical shape and producing many

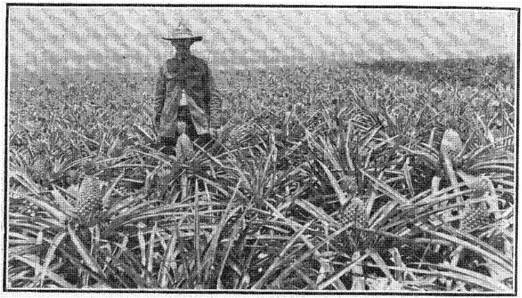

Fig. 7. A ratoon crop of the "Queensland" variety. Observe the great height of the fruit and the other characters referred to in Fig. 6.

slips on its stem. This is probably the variety which Capt. John Kidwell, the pioneer in commercial pineapple growing in Hawai, refers to as having been introduced from Queensland many years ago.[1] It appears to have persisted in cultivation on some of the plantations, mixed with the Cayenne, and the two have passed as one variety. The cone-shaped fruit is by no means as well adapted for canning as the Cayenne, and growers should segregate the varieties in selecting plants for new fields.

A third type may be found side by side with these that have been described. It also has a smooth leaf, but narrower than either of the others. The plant is of weak growth and appears very subject to disease and insect attack. It ratoons very poorly and sometimes fails entirely in this respect. It produces some slips, but less than the Queensland variety. The fruit inclines to the barrel shape, and is reported by some canners to be a good keeper, but inclined to white color of flesh, which is undesirable. This type is quite unsatisfactory, on account of its weakness and failure to ratoon. Whether it is a separate introduction or merely degenerate stock of the Cayenne, deteriorated through unfavorable conditions, can not be stated at present, but that it has given uniformly bad results on Kauai, wherever planted, there appears to be no doubt. The difference is so marked that these plants standing beside either of the others can readily be distinguished at a long distance. The stock is to be avoided, whether honored with a name of its own or not.

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[1] Hawaiian Forester and Agriculturist, Vol. I, No. 12.

The Red Spanish variety has been tried on a commercial scale in Hawaii, but has not met with favor. Its small size puts it out of the running with the Cayenne in these islands as a pine for canning. Quite a large number of varieties have been grown experimentally and some of these, as for example the Queen, are well worthy of a place in the fruit garden because of their excellent flavor and texture, but none of the varieties tested up to this time have claimed a place in the commercial plantation except the three described above. We have not, however, found the ideal pine, and other varieties should be tested and new kinds originated.

DISEASES.

Quite a number of the diseases of the pineapple have appeared in Hawaii, but fortunately only a few of these have caused much damage.[1]

SOFT ROT.

Soft rot is a name which has been applied to a disease affecting green or ripe pineapples. It has done some damage in the fields and en route to the cannery, but its greatest devastation has been wrought upon fresh fruit shipments to the mainland. The loss thus occasioned formerly often ran over 50 per cent and sometimes included the whole shipment. The disease is first observed as a soft and slightly discolored spot on the fruit, generally near the base, although it may occur at the crown or upon any part of the fruit. The tissue soon breaks down and becomes blackened. The disease is caused by the fungus *Thielaviopsis paradoxa,* which also grows upon sugar cane and exists in the soil. It probably enters the fruit most frequently through the cut stem or other exposed moist surface, but has been shown by Larsen[2] to be capable of penetrating the uninjured surface if suitable conditions are present. See fig. 8.

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[1] A careful study of the diseases of the pineapple in these islands has been made by Mr. L. D. Larsen, Asst. Pathologist of the Experiment Station of the Hawaiian Sugar Planters' Association, and the results have been published as Bul. No. 10 of the Pathological and Physiological Series. Readers who wish to pursue this phase of the subject in more detail are referred to that publication.

[2] Hawaiian Sugar Planters' Assn. Expt. Station, Pathological Series Bul. No. 10.

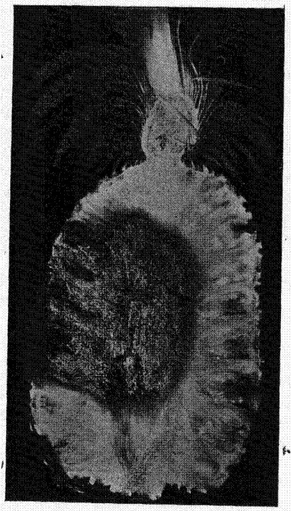

Fig. 8. Sectional view of pineapple affected with Soft Rot.
(Courtesy of H. S. P. A. Experiment Station.)

REMEDIES.

No single remedial measure will suffice for the control of this disease. The first steps should be along the lines of proper sanitation. Decaying pineapples should not be allowed to remain about the fields or the packing houses. The lug-boxes in which green fruit for shipping is to be carried should be free from spores. They may be spread out where the sunlight can enter them for several hours, or fumigation with formaldehyde will prove an effective means of destroying the spores that may be lingering in cracks and crevices.[1] The packing house must be kept clean, and if tight may be fumigated, but since most pineapple packing houses are open sheds an occasional spraying of the walls and floors with Bordeaux mixture would be easier. These suggestions are based upon recent knowledge of the fungus and have not yet come into general use.

The curing of the fruit by allowing it to remain upon its crown in the packing house has been found to be very beneficial. By this means several ends are gained. Any dampness that may be upon the fruit picked in rainy weather is eliminated, as also the excessive heat in pines gathered on bright days. The freshly cut stems should become shriveled and dried, and if any fail to do so they should not be shipped, as stated elsewhere.

A paper wrapping around each fruit, although not generally used in Hawaii, would prevent infection from spores in the ship or car, in addition to its other advantages mentioned elsewhere.

It is extremely important to provide on shipboard and elsewhere conditions that are unfavorable to the development of the disease. It is well known that dampness, high temperature and lack of ventilation are just the conditions in which the disease prospers, and these should not exist where fresh pineapples are in storage or in transit. The cutting of the subtending bracts, instead of pulling them off, and when the disease is prevalent the cutting of rather long stems on the fruit have both proved beneficial in the experiments conducted by this Station.

In early experiments formaldehyde fumigation was applied directly to the fruits in some cases and resulted in reducing the loss by decay, but it has been found in more recent experiments here that the gas in sufficient quantity to destroy all the spores[2] injures the green fruit by preventing it from acquiring its natural color in ripening. With the other precautions mentioned, however, there is not much difficulty in keeping the loss at a minimum on properly selected fruit from healthy plants.

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[1] To fumigate with this gas it is necessary to have an airtight room. The gas is easily liberated from commercial formalin by means of permanganate of potash. The formalin should be about 40 per cent formaldehyde and it is necessary to use from 2½ to 3 pints for every 1,000 cubic feet of space to be fumigated. Permanganate of potash should be used in the proportion of 7½ ounces for every pint of formalin. It is only necessary to place the permanganate of potash in the bottom of a large container, pour the formalin over it and leave the room. A violent reaction takes place and if the container is not large some of the fluid will be lost. The gas is not dangerous to work with, as is hydrocyanic gas, but the operator must be prepared to get out promptly.

[2] U. S. Dept. of Agr., Bur. of Plant Industry, Bul. No. 171, by Flora W. Patterson, Vera K. Charles and Frank J. Veihmeyer.

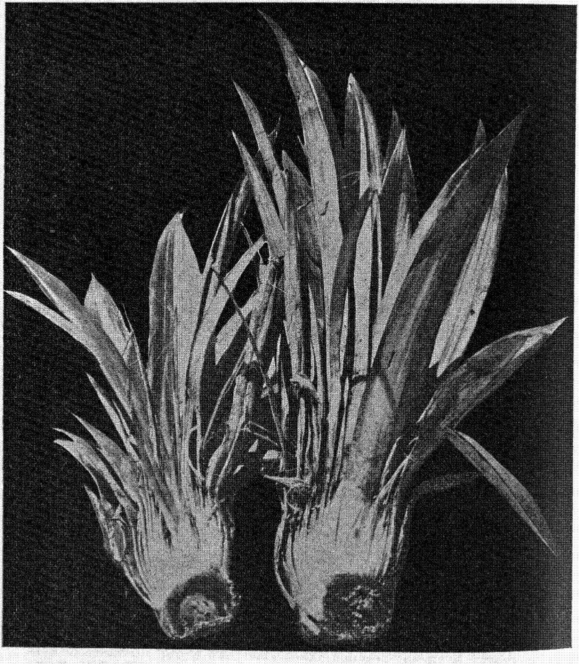

Fig. 9. Typical Base Rot of pineapple cuttings.
(Courtesy of H. S. P. A. Experiment Station.)

BASE ROT OF CUTTINGS.

The same fungus which causes the Soft Rot of the fruit has been shown to be the cause of the rotting at the base of suckers, slips or crowns[1] shortly after they have been planted or while they are in transit on shipboard or train. The rotting away of plants after they have been set out is familiar to all pineapple growers in Hawaii and often results in a very large percentage of loss. Larsen's experiments have demonstrated that this form of the disease may be kept well in control by stripping off only a few leaves at the base and allowing the plants to dry for one week before setting them in the ground. See fig. 9.

LEAF SPOT.

Leaf Spot is a disease that has been observed by the growers for many years, particularly in the winter time, but since its effects become less apparent as the summer returns, it has not been seriously thought of. It is characterized by spots of varying size and usually of a white or straw yellow color appearing upon the leaves. This also has been shown by Larsen to be caused by the same fungus (*Thielaviopsis paradoxa*) which causes the Soft Rot of the fruit and the Base Rot of the cuttings, and to be associated with the work of a grasshopper in its attacks upon the leaves. The injury in the leaf caused by the grasshopper furnishes a common means of entrance for the fungus, but it also gains entrance through other injuries to the leaf, such as those made by the rubbing of one leaf against another. Whatever may be done to reduce the spread of this fungus, as indicated elsewhere, will of course lessen the Leaf Spot. If it becomes necessary to take further steps in control, some measures should be taken against the grasshopper. See fig. 10.

BROWN ROT.

Brown Rot is an appropriate name applied by Larsen to a disease of the pineapple which is rather common in Hawaii, but which has given rise to little alarm. It may affect the exterior of the fruit, appearing as a brown spot upon the surface, or perhaps more commonly it may be seen in the tissues of the fruit just beneath the surface when it is sliced at the cannery. It does

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[1] Larsen.

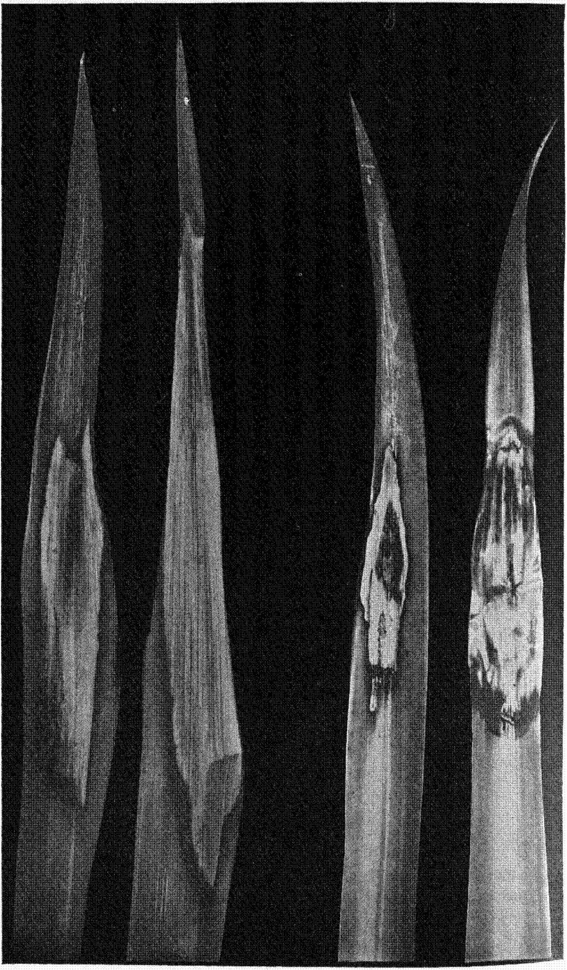

Fig. 10. Pineapple Leaf Spot. The two right hand spots were produced by artificial infection with **Thielaviopsis.** The two on the left are from natural infection, through punctures made by the spines of some neighboring leaves. (Courtesy of H. S. P. A. Experiment Station.)

not result in the breaking down of the tissues, as does the Soft Rot, but mars the appearance of the fruit externally and destroys certain slices for canning. A number of organisms appear to be capable of producing a similar appearance, but Larsen concludes that most of the injury of this nature in Hawaii is due to a fungus of the genus *Fusarium*. No remedy has been suggested for its control. See fig. 11.

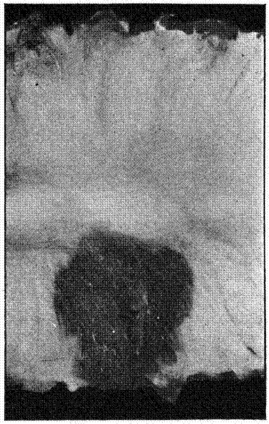

Fig. 11. Cross section of pineapple, showing infection with Brown Rot. (Courtesy of H. S. P. A. Experiment Station.)

SUN SCALD.

When, through weakness of the stem or other injury, a pineapple falls over and lies in a nearly horizontal position the direct rays of the sun upon the exposed side often produce an injury which has been called Sun Scald or Sun Burn. The injury may be only slight, affecting merely the appearance of the fruit on the surface, which becomes a pale green color while the remainder of the pine is unripe and a light yellow or white when the fruit ripens. In more severe cases, however, the whole side of the fruit is arrested in its development and the tissues within become insipid or even dry and pithy. The conditions which result in the falling of the fruit are several. A general weakness of the plants arising from improper soil conditions is a prevalent cause. Sun Scald is very common on highly manganiferous soils, where the plants show so many of the symptoms of weakness. In healthy fields plants often fall over because suckers too high up on the stem have been selected for the ratoon crop or because the soil has not been sufficiently drawn up about the plants. The weight of the fruit itself, with so great a leverage and aided by the wind, causes the branch to partly break off and fall until it rests upon the ground or upon an adjacent plant. Suckers for the ratoon crop should be selected as low down as possible, where the soil can be drawn about them.

WILT.

Wilt is one of the most wide spread of pineapple diseases and is known in nearly all countries where this fruit is grown. It exists in Hawaii, but with the exception of a few fields has not caused great damage. The disease is characterized by the wilting or loss of rigidity of some of the leaves, which fall upon the ground and become useless. As the disease extends it includes all the leaves and the plant dies. The leaves often turn reddish or yellow before they wilt. The cause of the malady has not yet been discovered and little is recommended by way of remedy except to remove diseased plants. Extra tillage about the affected plants is claimed by the growers to be beneficial. (See fig. 12.)

TANGLEROOT.

Tangleroot is a term applied to an unnatural condition in the roots of the pineapple, whereby they wind themselves about the base of the plant and fail to spread out into the soil. The condition does not usually manifest itself to any serious extent on plants that have been properly stripped at planting and which are cared for by good tillage.

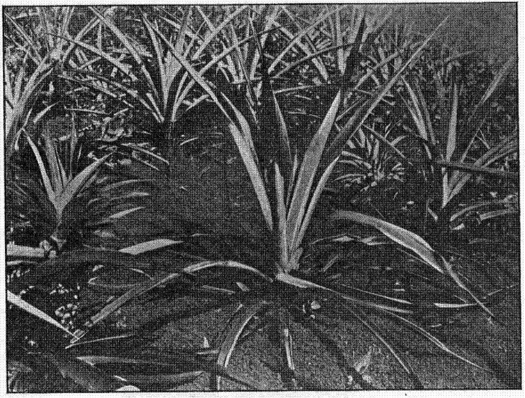

Fig. 12. Plant affected with pineapple Wilt. (Early stage.) (Courtesy of H. S. P. A. Experiment Station.)

INSECT PESTS.

D. T. FULLAWAY.

There are very few insect pests of the pineapple plant in Hawaii, and the losses thus occasioned are fortunately so small that it is ordinarily unnecessary to attempt any artificial control.

The commoner insect enemies are known respectively as the "pineapple scale" and the "pineapple mealybug." These apparently dissimilar insects both belong to the rhynchotal family Coccidae, characterized by sucking mouthparts, the absence of wings in the female, and a general sedentary habit. They are a widespread group, with which every horticulturist is familiar, and generally cause considerable damage, both in greenhouse and field.

The pineapple scale (*Diapsis bromeliae*) has already received attention from the station entomologist and is reported on in Press Bulletin No. 10, by D. L. Van Dine, to which the reader is referred for more detailed information. The female scale is small, flat and circular, yellowish brown (darker outside) with a white rim, beneath which the soft-bodied, golden yellowish insect is concealed, and is usually found thickly on the leaves and sometimes on the fruit. The male scale is long and thin, entirely white, with three longitudinal ridges. (See fig. 13.)

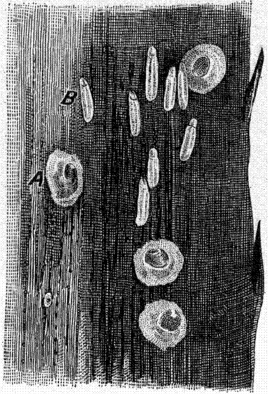

Fig. 13. Pineapple scale (Diaspis bromeliæ)
a. Female scale. b. Male scale.

The pineapple mealybug (*Pseudococcus bromeliae*) is much larger than the scale, is soft-bodied, with well developed legs, is more or less convex above and in color yellowish brown beneath the waxen coat which makes it appear entirely white. The male has not been seen. This mealybug has formerly been confused with *Pseudococcus citri,* from which it differs in the absence of a sac.. (See fig. 14.)

Both of these insects damage the plants by withdrawing the cell sap through the tubular cavity of the beak, which is thrust into the tissues. The loss of the plant juice causes withering, and the puncture gives access to the spores of parasitic fungi. Rarely, however, does either scale or mealybug become numerous enough to cause widespread injury. Presumably they are con-

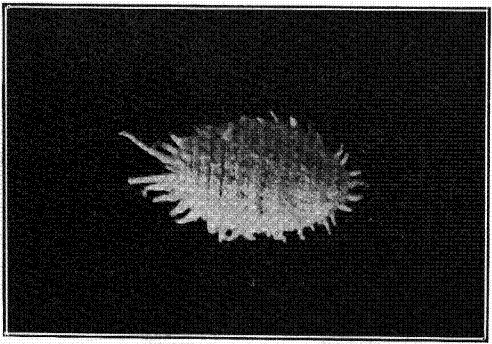

Fig. 14. Pineapple mealy-bug (Pisendocaccus bromeliæ), female.

trolled in a degree by parasites and predators Several aphelinid species have been bred from the scale, and the mealybug is destroyed by both coccinellid beetles (*Cryptolaemus montrouzieri, Rhyzobius ventralis*) and by hymenopterous parasites (*Coccophagus spp.*). Ants are very active in spreading and protecting the mealybug and are a prolific source of trouble.

When it is necessary to use insecticides to control the scale insects, kerosene emulsion and miscible oil sprays are recommended, or a small amount of tobacco dust, which is to be sprinkled over the tops. When it is practicable to fumigate with hydrocyanic gas, a cheaper and more effective treatment is possible.

Within recent years a locustid grasshopper (*Xiphidium varipenne*) has periodically attacked pineapple plants, gnawing large holes in the leaves. Fungus attack quickly follows the mechanical injury to the tissue and the leaves wither and die. The damage has not been extensive and probably never will be, as the grasshopper is controlled by an egg parasite, but the injury is usually apparent enough to attract attention and has occasionally produced alarm. (See fig. 15.)

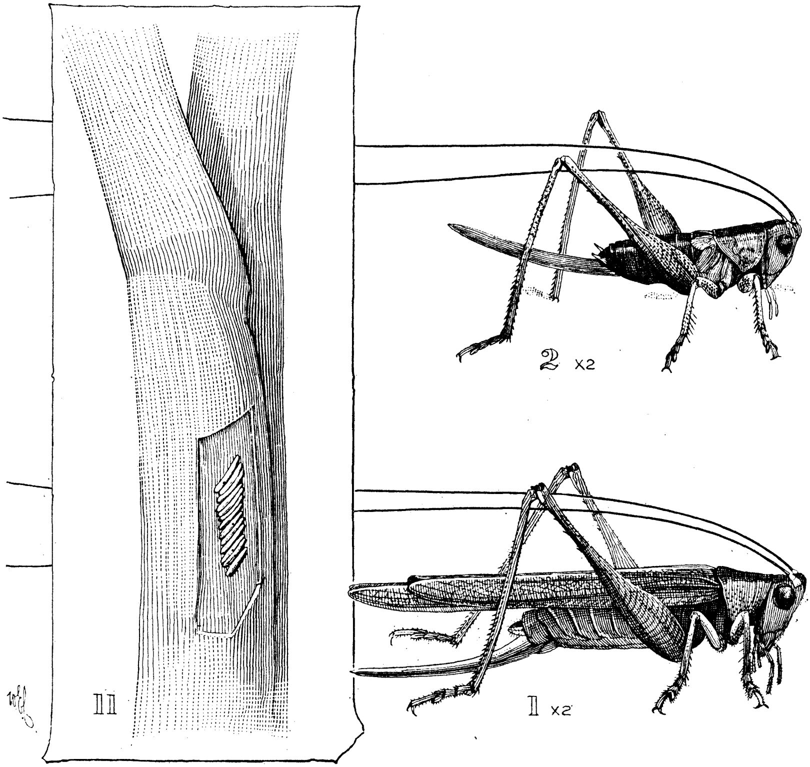

Fig. 15. Grasshopper (Xiphidium varipenne)
1 female. 2 nymph. 11 eggs.
(Copied from Swezey).

Pineapple growers will be interested to know the identity of certain insects usually found around the factory dumps and refuse piles in the fields. The vinegar fly (*Drosophila ampelophila*), a nitidulid beetle (*Carpophilus humeralis*) and the ortalid fly (*Euxesta annonae*), breeding in decaying fruit and trash, are invariably found in such places and are readily recognized. Several caterpillars also, which breed in situations affording dry dead vegetable matter, along with their moths, are found around ripening and overripe fruit in the field. None of these can be classed as harmful.

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HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN, NO. 37.

EUPHORBIA LORIFOLIA,
A Possible Source of Rubber and Chicle.

BY

WM. McGEORGE, ASSISTANT CHEMIST

AND

W. A. ANDERSON, SUPERINTENDENT RUBBER SUBSTATION.

PHYSICAL AND CHEMICAL PROPERTIES OF LATEX OF EUPHORBIA.

BY

WM. McGEORGE.

Developments brought forward, during the last ten years, in the commercial aspect of the rubber industry, due to the wide range of uses to which this product may be applied, have caused a wide spread investigation upon the physical properties and chemical composition of the latices from practically all the common latex-bearing trees and shrubs. These researches have been partly stimulated by the apparent failure, heretofore, of placing the manufacture of synthetic rubber upon a commercial basis of sufficient remuneration to compete with the natural product. On the other hand additional stimulation has been derived, for both the manufacture of the synthetic product and the investigation of latices, by the high price which rubber has been able to maintain. While there is room for doubt as to whether scientists will ever be able to duplicate the natural rubber with a synthetic product, it is almost an absolute certainty that a synthetic substitute will, in the near future, be made an article of commerce.

While these investigations upon latices have been primarily stimulated by a search for a new source of rubber, nevertheless they have brought out developments of some value concerning the resin content. Since this substance is known to be a constituent in widely varying quantities of all latex-bearing as well as some non-latex-bearing trees.

At present the only latex-bearing trees of known commercial value in Hawaii, are those which are used as a source of rubber and are largely Ceara, Para and Castilloa. Limited numbers also exist of Manihot dichotoma, M. piauhiensis, Ficus elastica, F. religiosa, and species of Cryptostegia, Sapium, Kickxia, Calotropis and other genera.[1]. The attention of this station was called to a species of Euphorbia (Euphorbia lorifolia, native name Koko or Akoko, meaning blood) which contains an unusually large quantity of easily obtained latex and occurs in large numbers in these islands. The first sample was sent into this laboratory by Mr. J. F. Rock and was taken by him from trees on the island of Hawaii, covering several thousand acres on that island alone. The area is at present under lease for pasturage, however, large areas of this same tree are said to exist upon the other islands of the group. In view of the ease of obtaining the latex, in other words, the ease of tapping and the large quantities of latex which can be obtained from one tree, coupled with the large areas which exist in the islands, it was considered to be of sufficient importance to warrant some investigation as to the composition and properties of this latex.

Commercial importance attaches to any rubber yielding latex which may be obtained in reasonably large quantities. Euphorbia lorifolia, the tree reported upon in this bulletin, occurs in a continuous area of 6000 acres in one section of Kona. The yield of latex shown by the experiments reported herein is remarkable, indicating as it does the possible collection daily per laborer of 34 pounds dry substance or 20 pounds pure resin, without considering the rubber content of the latex. The comparison of the whole latex of Euphorbia and Ceara rubber is of interest in showing a very high proteid content in Ceara latex. The fact that the proteid material is so largely removed by washing and pressure indicates how easily this material is removed from the rubber.—E. V. WILCOX.

[1] See Hawaii Experiment Station Bul. No. 19.

EXCHANGE
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Accordingly a large quantity was obtained and considerable work and time spent upon obtaining information regarding its physical and chemical properties.

PREVIOUS WORK ON EUPHORBIA.

So far as is known this particular species of Euphorbia is found in no other part of the world, being a native of Hawaii. However, this tree is of a widely distributed genus and some previous work has been done upon this genus of trees and plants to escertain the nature of the latex and its caoutchouc-content. H Journelle[1] reports on E. elastica, a native tree of Madagascar which yields a good quality of caoutchouc and is easily coagulated by boiling. The yield of caoutchouc he stated to be at least 320 grams per litre of latex (about 11.3 oz. per quart). He also merely mentions another species of rubber-bearing Euphorbia; namely, E. intisy, a native shrub of Madagascar. J. McC. Sanders[2] reports a species (E. elastica, Palo amarillo) growing in Mexico the latex of which contains about ten per cent of rubber and the coagulated product contains about 50 per cent resins. P. Olsson-Seffer[3] reports concerning E. fulva (Palo amarillo) a tree occuring in Mexico the latex of which contains 7.3 — 15.7 per cent rubber and 19 per cent upwards of resins. Commenting upon this latex he says it might possibly be commercially exploited as a source of rubber. O. Rebuffat[4] analysed the latex of E. candelabra, which grows abundantly in Eritrea, Africa, and claims to have found 40 — 50 per cent of good quality rubber in it. An analysis of the latex of E. lactiflua[5] shows it to have a resin content of about 28 per cent and about 4.1 per cent caoutchouc. N. H. Cohen[6] worked on the latex of a South African Euphorbia, the coagulated form of which contained 70 per cent of resins. In addition a great deal of work has been done upon the medicinal value of Euphorbia shrubs, many of which are known to contain alkaloids.

Some of the results above referred to are open to serious questions as to the caoutchouc content. Especially the E. elastica

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1. Comptes Rend. 1905, 140, 1047-1049.
2. An. Inst. Med. Nac. (Mex.) 10 (1908) pp. 67-74.
3. Daily Cons. & Trade Rep. (U. S.) 1909, No. 3516.
4. Atti. R. Inst. Incoragg. Napoli 6, Ser., 59 (1907) p. 89.
5. An. Agron. (Santiago de Chile) 4 (1909) No. 3-4 pp. 189-237.
6. Arch. Pharm. 1908, 246, 515-520.

the analysis of which shows 30 per cent of caoutchouc, and more especially E. candelabra the analysis of which shows a rubber content of from 40 — 50 per cent. However, these high results may be explained by the probability of the analyst reporting resin with the caoutchouc. The latex of Para rubber contains only about 40 per cent caoutchouc.

PROPERTIES OF LATEX FROM EUPHORBIA LORIFOLIA.

The latex is white, viscous, has milky appearance, strongly acid reaction, and a rather pleasant aroma peculiar to itself. It is of a rather highly combustible nature when the moisture is evaporated off and burns with a strong flame and dense smoke fumes. The latex has a special gravity of about 1.045 at 20°C. and quickly darkens on contact with the atmosphere, which is probably due to an addition product formed between the oxygen of the air and the unsaturated hydrocarbons of latex. However, there is also a strong possibility of this darkening being due to the proteids. This same property of darkening is noticeable upon the tree. In this form the latex is capable of being re-emulsified on mixing with water. The latex does not ferment readily and can be preserved indefinitely without even a coagulation or separation, by the addition of a small quantity of formalin. Under the high power microscope glubules are only faintly discernable.

COAGULATION.

At the outset it was found that most of the ordinary methods of coagulation were without apparent effect upon this latex. Accordingly a series of methods of coagulation were planned and the following results obtained:

1. Acetic acid when added in small quantities produces no coagulation even on long standing, but upon the surface of the latex where the drops of acid strike, the particles are set into a rather violent action and appear to be temporarily coagulated about the drop of acid, but upon strirring this disappears. This suggested the possibility of producing a coagulation with larger quantities of acetic acid with the result that it was found that by addition of extremely large quantities (about 1 part strong acid to 1 part latex) the latex thickens upon stirring and the whole coalesces into a mass, the physical condition of which is

similar to the white of an egg. Other acids were without effect.

2. A small quantity was treated with ammonium oxalate diluted and a small amount of calcium chloride added. There was a precipitation of calcium oxalate but no coagulation of latex.

3. Dilution with water was without effect even upon long standing.

4. Neutralization with alkali produced no coagulation.

5. On addition of enough alkali to produce a 6 per cent solution, no coagulation resulted.

6. Acid juice of the sisal plant was tried to see the effect of plant juices, and it appeared to act similarly to the acetic acid, with no coagulation.

7. Salt solution (sodium chloride) was without effect.

8. Formalin produced no coagulation, alum and soap solution likewise.

9. Lead acetate acts as a precipitant and carries down the whole mass, leaving a clear supernatant liquid, while alumina cream, another clarifying agent was without effect.

10. Ammonium sulphate, generally recommended as a precipitant for proteids and albuminoids was without effect except when added in the form of the dry salt in large quantities. The action of the salt was to remove the water from the latex to form a solution, which removal left the latex in a coagulated condition from which re-emulsification was incomplete.

11. Addition of alcohol to the latex acted similarly to acetic acid, namely, small quantities were very ineffective. On gradually increasing the proportion of alcohol and stirring the whole up to a certain stage it gradually coalesces into a strongly viscous mass. Addition of alcohol beyond this stage causes a reversion of the mass to its original liquid state. On the other hand pouring or better spraying the latex into alcohol produced immediate coagulation into a "cheesy" mass which will not re-emulsify by subsequent prolonged boiling with either alcohol or water.

12. Action of heat. This proved to be the most promising method of coagulation. Up to a temperature of 75° C. the latex maintains its original form but between 80° — 90° C. the latex thickens and at about 90° C. assumes a "cheesy" form. This mass will partially re-emulsify upon boiling with water immediately but if maintained at 90° C. for several hours to

become thoroughly coagulated and the whole allowed to remain until the following day to cool, it then will remain in its coagulated state even on prolonged boiling with water. This mass is cohesive and can easily be rolled into balls which on standing in the air turn brown and lose moisture quite rapidly.

Of the above methods Nos. 11 and 12 are the only ones which were effective and No. 12 is the one most recommended for a coagulant. The coagulation obtained is not one in the sense generally spoken of in reference to rubber latices, that is, there is absolutely no separation of clear liquor, upper layer of caoutchouc, etc. But the whole action may be better described as a coalescing of the entire latex into one mass, moisture included. This mass is extremely adhesive but does not possess the strong cohesive properties of a coagulated latex from Para or Ceara trees and does not appear to contain a very large per cent of caoutchouc, but to be composed in greater part of resins.

ANALYTICAL RESULTS.

In order to make an analytical examination upon the latex it was necessary to work upon the "cheese." The action of solvents such as chloroform, benzol, carbon bisulphide, etc., when shaken with the milky latex only increased the volume of the emulsion. Accordingly analyses were made upon the "cheese" by using a series of extractions using alcohol first, then acetone followed by chloroform. The following results were obtained.

COMPOSITION FO LATEX IN PER CENT.

	1	II	III	IV
Alcohol extract	50.66	35.17	37.24	37.10
Acetone extract	10.46	19.90	22.60	17.45
Chloroform extract	14.79	14.24	17.34	14.72
Insoluble residue	24.09	30.69	22.79	30.73

These results are given on the basis of a moisture free latex. The alcohol extract represents gums, carbohydrates and resins, the acetone extract the resin insoluble in alcohol and the chloroform extract was a caoutchouc-like substance, and will hereafter be referred to as caoutchouc. The insoluble residue was obtained by difference and will be described later. The four samples represent three different tappings: No. 1 was obtained by extraction in the cold; that is, by allowing it to stand in contact with solvents at room temperature, No. 2 is the same sample extracted with boiling solvents, while Nos. 3 and 4 are separate tappings extracted with boiling solvents. A more complete analysis of the latex is as follows:

MOISTURE AND SOLID MATTER.

	per cent I	per cent II	per cent III
Solid matter	41.59	40.92	49.15
Moisture	58.41	59.08	50.85

ANALYSIS OF SOLID MATTER.

Gum	1.50
Resins	55.95
Caoutchouc	15.80
Protein	12.66
Reducing sugars	trace
Nonreducing sugars	.68
Pentosans	.84
Ash	3.44
Undetermined	9.11
	100.00 per cent.

The above analysis represents the average results of the analyses made upon two tappings. For clearness it may be necessary to state that the gum (1.5 per cent) was obtained by treating the alcoholic residue with water and determining the per cent of this water soluble constituent. Of course this will also contain part of the sugars referred to in this same table but by no means all of them, as the carbohydrates are not all completely soluble in alcohol. The remainder of the alcoholic residue was added to the acetone soluble resin and the whole classified as resins, even though there is considerable difference in the color and other properties of the two resins. The latex contains no starch at least not in sufficient quantities to be detected with iodine.

COMPOSITION OF THE ASH.

Silica (SiO_2)	.89
Iron and (Fe_2O_3) Aluminum oxides (Al_2O_3).	1.64
Manganese)Mn_3O_4)	.00
Lime (CaO)	6.07
Magnesia (MgO)	14.76
Potash (K_2O)	12.94
Soda (Na_2O)	21.72
Sulphur trioxide (SO_3)	3.90
Phosphoric acid (P_2O_5)	1.66
Carbon dioxide (CO_2)	36.42

This table indicates that the mineral portion of the latex is made up of the more soluble constituents of the soil.

ALCOHOL-SOLUBLE MATTER.

On extracting the coagulated latex with alcohol a yellow solution is obtained which on cooling deposits a flocculent residue. On evaporation of the whole to dryness a dark brown resin is obtained which is more or less brittle at room temperature and softens at 50° C. and as stated above contains a small per cent of water soluble gums. A short study was made upon the nature of this resin and an attempt made at a classification. The following values were obtained: Acid value 9.46, Saponification value 38.10, iodine number 152.30.

Resins are classified by Allen[1] according to their content of resin acids, resin esters and resenes, the latter being apparently inert bodies of unknown composition. The acid value was obtained by titrating an alcoholic solution of the resin, while the saponification value was obtained by saponifying the resin with alcoholic potash and determining the amount of potash used up in the reaction. Figures represent milligrams of potassium hydrate per gram of resin. These figures are comparatively lower than a great many resins and indicate that the content of resin acids and esters is rather low and that the substance is in large part either an anhydride of a resin acid or to be classified as an indifferent resene compound. The iodine value is fairly high and indicates the unsaturated condition of this organic substance as shown by the readiness with which it combines with iodine chloride (I Cl). The iodine absorption was carried out according to the Hübl method and absorption allowed to proceed only three hours, as the iodine value was found to vary greatly with the time.

ACETONE EXTRACT.

This extract was also a yellow solution, but lighter than the alcohol extract. On evaporating this to obtain the resin, a vitreous, almost transparent resin, of a reddish yellow color was obtained. This resin is apparently a very good product, brittle at room temperature and softening at about 65° C. A short study of the nature of this substance revealed the following data: Acid value 0.0, Saponification value 0.0, iodine number 163.0.

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[1] Allen, Com. Organic Chem. Vol. II, pt. III p. 141.

This product undoubtedly is to be classed as a resene compound. It is not acted upon by boiling with alkali, in other words is unsaponifiable. Allen says of these compounds that "they possess no characteristic chemical properties and do not appear to be alcohols, esters, acids, ketones or aldehydes." This class of resins is used in the manufacture of varnish, their value being due to their chemical inactivity. Tschirch[1] presents the theory that this class of compounds belongs to the oxyterpenes or oxypolyterpenes.

CAOUTCHOUC.

The portion of the latex soluble in chloroform is radically different in its physical properties from the two previous extracts. Upon evaporation a caoutchouc-like substance is obtained which remains soft and sticky at ordinary temperatures. The extraction with chloroform is complete, and easily filtered from the insoluble residue, which indicates the absence of the insoluble residue characteristic of Para and Ceara latex which swells upon treatment with chloroform and renders the extraction with this solvent incomplete. While there is no question of the solubility of caoutchouc in chloroform, its action is greatly retarded in the Para and Ceara rubber by the presence of this insoluble constituent the composition of which Weber[2] found to be expressed by the formula $C_{30} H_{68} O_{10}$. The action of chloroform on Euphorbia rubber as noted above indicates the absence of such an oxygenated compound in the rubber from this tree.

No tests were made to prove absolutely that this chloroform soluble matter is pure caoutchouc chemically, beyond its solubility in various solvents. A solution of it in chloroform or carbon bisulphide is precipitated out as a white precipitate on pouring into alcohol or acetone. While this is one property of rubber it is not proof of its presence as other hydrocarbons insoluble in alcohol and soluble in chloroform may have the same properties. It hence only indicates the possibility of its being caoutchouc. J. Torrey[1] has proposed a colorimetric method for the determination of rubber based on the deep red color pro-

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1. **Tschirch "Die Harze und die Harzbehaeter" 2nd ed. p. 1079.**
2. **Jour. Soc. Chem. Ind. 1900, p. 215.**

duced when rubber is heated in nitric acid (sp. g. 1.42) and then the whole dissolved in alkali. The product from Euphorbia responds to this reaction beautifully, but the two resins obtained also react with equal intensity. While it was not considered of sufficient importance to make an elaborate study of this substance to prove absolutely its composition, from the data obtained I am of the opinion that it would be identified as a caoutchouc body. However, it appears to be an inferior grade of rubber and lacks the strong cohesive properties.

INSOLUBLE RESIDUE.

The residue left from extractions with the above solvents is a white flaky substance which can be ground to a rather fine powder. While it appears to contain a small per cent of gum or resin it is apparently insoluble in all the common solvents. The most striking thing noticeable is the high nitrogen content, which amounted to 6.88 per cent and is equivalent to nearly 50 per cent protein. Subsequent tests to prove the presence of proteids gave positive results. Millon's reagent (a solution of mercurous nitrate, holding nitrous acid in solution) gave a reaction for proteids both in this insoluble residue and in the original latex. Other minor tests were obtained which added to the proof of the presence of this class of compounds in appreciable quantities. This residue is not acted upon by any of the strong acids at ordinary temperatures but when boiled with strong alkali forms a colloidal solution which on standing precipitates as a flocculent precipitate.

In view of the fact that the presence of alkaloids has been claimed in Euphorbia, several of the more important methods of detecting this class of compounds were applied to the latex and also to the insoluble residue, none of which indicated their presence.

DRY DISTILLATION.

On subjecting this latex to destructive distillation some interesting results were obtained, thus opening up a line of work which would require a thorough study to reach any conclusion as to the nature of the distillation products. I will only briefly state that the main product is a resin oil with a green fluorescence similar to crude petroleum, which amounts to about

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1. **India Rubber Jour. 1905, 30, p. 417-18.**

25-30 per cent of the original latex and passes over at about 250° C.

DISCUSSION.

The physical constitution of the caoutchouc bearing latices is generally considered to be an emulsion, the stability of which depends upon the maintenance of a state of equilibrium within this emulsion. The coagulation of the latices consists essentially in disturbing this equilibrium with the aid of chemical or physical means. Thus bringing about a segregation and subsequently an aggregation of the particles making up the emulsion, those of specific gravity lighter than water (which would include caoutchouc and many resins) would rise to the surface, and since these constituents are the dominating ones, they would carry the major part of the remaining constituents such as mineral matter, carbohydrates, proteids, etc., with them. These latter substances, howover, are removed in large part by subsequent washing.

Since the Euphorbia latex refused to respond to most of the latex coagulants commonly used and since it is readily coagulated by means of alcohol and heat, (both of which are coagulants for albuminoids and proteids), it would seem that the coagulation of Euphorbia latex is primarily due to the coagulation of these bodies. A thorough explanation of the phenomeon of coagulation which is acceptable to all interested, is yet forthcoming. However, I am of the opinion that the proteids are a big factor in the above method of coagulation. Different forms of proteids being affected or unaffected by physical or chemical agents according to the properties of the proteids present, offers a theory as to the action of various coagulants, and why the different coagulants act so differently on latices of various sources and properties. Furthermore the action is apparently a physical one.

The resolution or re-emulsification which the Euphorbia latex undergoes on adding an excess of alcohol as previously referred to is probably due to a resolution of the proteid in this solvent. Heat and alcohol both being dehydrating agents, offers an explanation of the coagulation as being a result of dehydration but at all events, even though this be partially true, the effect upon the proteid appears to be the dominant factor.

The function of latices is also a matter yet open to wide discussion. For this reason, primarily, the mineral constitutents of the ash were determined and have been tabulated, as well as the carbohydrate and nitrogen content. Some investigators have advanced the theory that the latex is an excretory product of the plant, others that it acts as a source of stored up energy, and D. Spence[1] likens its function in rubber trees to that of glycogen in the liver. The theory of its acting as a source of plant food appears the more acceptable from data at hand, namely, high nitrogen content and the composition of the mineral constituents. Coupled with this is the fact that the green fruit of the Sapotaceae (source of Balata rubber) contains a latex which is lacking in the ripe fruit. There is also a strong possibility of the latex acting as a moisture conserving agent for the plant and, through the moisture content of the latex, as a conveyor of plant food.

COMPARISON OF EUPHORBIA WITH CEARA AND BALATA.

In order to compare the properties of the Euphorbia latex with some of the other latices obtainable at the Experiment Station, samples were collected from Ceara and Balata and the resin and caoutchouc content examined. Balata being identical with the so-called chicle, the main constituent of chewing gum, it was considered to be of sufficient importance to compare these resins, since the Euphorbia resin serves as an excellent substitute for this purpose. And while the physical properties of the two latices appear to differ as well as the physical form of the caoutchouc the resins soluble in alcohol and acetone are similar. On the other hand the resins from the Ceara were soft and entirely different from the other two. The following table gives a comparison of analyses made upon the three varieties of latex.

LATEX ANALYSES.

	Balata per cent	Ceara per cent	Euphorbia per cent
Resins alcohol soluble	42.80	7.28	34.70
Resins acetone soluble	4.91	1.30	21.25
Protein	4.35	13.16	12.66
Ash	not det.	2.54	3.44
Caoutchouc	13.95	75.72	15.80

The caoutchouc was determined in the Ceara by difference for reasons already referred to while that in the other latices was determined by extraction with chloroform. It is impossible to make an extraction of Ceara by chloroform in a reasonable length of time. The insoluble residue left from the balata amounted to 38.4 per cent and was unlike that of the Euphorbia in that if contained a higher per cent of an insoluble gum or resin. A sample large enough to make a further study of this product was not obtainable, this sample being taken from a number of green fruits. The Ceara latex was obtained from trees on Tantalus which had not been tapped for about two years.

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[1] Biochem. J. 3, 165.

Weber[1] comments upon the protein content of latices and considers the presence of as much as 5.6 per cent in a dry latex of unknown origin and also another of Para containing 4.3 per cent, highly questionable. All the figures obtained in my analyses were duplicated and several different tappings analysed from which there is no possibility of the high percentages of protein being abnormal.

SUMMARY.

The best means of coagulating the latex from Euphorbia lorifolia is with heat or by spraying the latex into alcohol. The former method appears to be the preferable.

The constituents which appear to be of most commercial value are the resins, the acetone soluble resin being a product of very fine texture and physical appearance.

The chaouchouc like substance appears to be of an inferior quality in comparison to the better grade, however, it might find use as a low grade product.

Distructive distillation of this product or possibly of the wood from this tree presents an unexplored field which may possibly offer a theme for future work. By distilling wood and all a more complete recovery would be possible.

In event of a commercial working of this latex by means of volatile solvents, the insoluble residue with its 40-50 per cent protein would have as a means of its disposal a possibility of its sale as a fertilizer on account of its high nitrogen content.

Acknowledgements are due Dr. E. V. Wilcox and Dr. W. P. Kelley for interest taken in this work as well as valuable suggestions offered from time to time, also to Hind, Rolph & Co. for their co-operation in securing the samples of latex and to Mr. Valentine Holt for obtaining the sapota fruit.

The Chemistry of India Rubber, C. O. Weber, p. 5.

OCCURRENCE OF EUPHORBIA LORIFOLIA AND TAPPING EXPERIMENTS.

BY

W. A. ANDERSON.

In February, 1912, announcement was made of the discovery on Hawaii, by Mr. J. F. Rock, of a forest of native trees belonging to the Euphorbiaceae. The yield of latex from these trees, as reported by Mr. Rock, was so large as to invite further investigation with a view to determining their commercial possibilities as rubber producers. The writer visited the forest in May for the purpose of securing latex samples, and of observing the adaptability of the trees for tapping, and the possibility of adding them to the varieties now being cultivated in the Territory for rubber.

The trees are growing among other forest growth on several thousand acres of Government land under lease to the Puuwaawaa Ranch, in the Kona District, Island of Hawaii. They are said to occur elsewhere, notably at Kukaiau where they are known by the Hawaiian name of "Koko" (bloody or juicy tree.) They were found at an elevation of about 3,000 feet, in very thin a-a soil with frequent out-croppings of pahoehoe The trees large enough for tapping are distributed at irregular intervals among other trees. The ground is covered with seedlings one to six or eight feet high, mostly of the Euphorbia trees, forming an immense nursery. There is very little undergrowth beside these seedlings. Many of these have been eaten off at the top by cattle, and have started growing again from eyes along the stems. The region is very dry, with a precipitation of not over twenty inches per year. At the time of the visit, at the end of what is usually the rainy season, only one inch of rain had fallen in five months. At this time the trees were putting forth new leaves, and appeared to be just entering on the summer's growth. This was taken to indicate ability to survive severe drouths.

The normal size of mature trees cannot be judged from the present forest. No large trees were seen, the largest being not over ten inches in diameter. A number of dead and dying trees no larger than this were noticed. But no conclusion can be drawn from this as to the size they might attain under favorable conditions. The thin soil, frequent severe drouths, and the cattle, combined, may have prevented the trees reaching full maturity.

To get further information on this subject, as well as to determine their adaptability to different conditions, a number of the seedlings were taken to Nahiku, and planted at the substation in deep, cultivated soil, at an elevation of about 700 feet, with a rainfall of over 100 inches per year. These started growing immediately and at the end of one month some had grown three inches. They will furnish material for observing the rate of growth under cultivation, and their suitability as a plantation tree.

TAPPING.

The tapping of the forest presents no serious obstacles. While the a-a is somewhat difficult to walk rapidly on, the absence of undergrowth, aside from the seedlings above mentioned, makes access to the trees easy. In the portions visited, there are about 50 to 75 mature trees per acre, at distances which, while naturally irregular, are not too great for successful tapping. By judicious thinning of the other forest trees and allowing the seedlings to grow at proper intervals this irregularity could be gradually overcome, and a forest developed with trees regularly spaced and at any desired distance apart.

Some of the trees had been tapped in February. Those which had been tapped by a series of diagonal incisions, a foot or so apart, had apparently suffered little injury. Some of these were tapped again May 28th and the flow was about the same as in February. This would indicate that they can be tapped as often as once in three months. They cannot be tapped every day. Each incision draws the latex for several inches from the cut, and tapping on the following day gives little flow.

The latex flows very freely and in large quantities. It spurts out apparently under considerable pressure, and flows rapidly for a few seconds, after which it flows more slowly for about a half hour. From the first six trees, tapped in the forenoon, about two and one-half pounds of latex was obtained. Other trees, tapped in the afternoon, gave a much smaller yield. The latex is very sticky and resinous. Where it had dried on the tree since the February tapping, it resembled spruce gum in appearance, feel and taste. It has an acid reaction as it comes from the tree, but shows no tendency to coagulate in bulk. Considering the fact that the trees were tapped when the foliage was very light, during a drouth which had lasted for five months, and near the middle of a bright, sunny day, the yield of latex was very large.

The conclusions drawn from the observation of this forest are: That the trees will grow on very thin soil, at high elevations, with small rainfall, and will live and yield large quantities of latex through long and severe drouths; that they reproduce freely, and the seedlings are very hardy; that they can be tapped much like the Castilloa tree, and about as often; and that this particular forest furnishes an excellent opportunity for proving the value of the tree as a rubber producer, providing, as it does, trees large enough for tapping, and near enough together, and in large enough numbers to tap economically.

Tapped by the full herring bone system, with U shaped excisions supplemented by incisions in the bottom of these cuts, as is done on some Mexican Castilloa plantations, one experienced man, on reasonably even ground, can tap about 200 trees per day. With an average yield of, say, one half that reported for the six trees mentioned above, one man could thus collect 41 2-3 pounds of latex in one day's work. The profitableness of the operation then depends on the amount of commercial material in the latex, the cost of getting it out, and its market value. The latex obtained was forwarded to the Station at Honolulu for coagulation and analysis.

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Issued October 20, 1912.

HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN NO. 38.

The Use of Dynamite in Farming.

BY

E. V. WILCOX.

DIFFICULTIES IN DRAINAGE AND AERATION.

One of the chief problems in successful farming in Hawaii is the maintenance of the proper physical condition of the soil. Many soils are extremely heavy, being composed of fine clay and silt. Such soils are easily puddled and compacted, thus becoming relatively impervious to air and water.[1] While there is rarely, if ever, a true hardpan underneath the ordinary cultivated surface of Hawaiian soils, the soil beneath the depth to which cultivation is ordinarily practiced soon becomes fully as hard and impervious as the hardpans which have given so much trouble in California, the Southern States and other parts of the mainland. This sort of hardpan which is really a mere compacting of the soil from the combined effects of moisture and pressure, is observed in a large proportion of the gardens and cultivated fields in Hawaii. No matter how deep the soil may be plowed nor how thoroughly it may be harrowed or pulverized before planting, a layer of compact soil is soon formed just below the depth to which the cultivator may reach. This compacting becomes more pronounced as time goes on until in fields upon which are grown such crops as pineapples the lower layers of the soil are altogether too firm for the best root growth or for the penetration of air or water long before the first crop reaches maturity. Since it is the ordinary custom to take one or two rattoon crops from the same field, the soil naturally becomes more and more unsuited to the best growth of the rattoon crops. It is a common matter of observation that while the upper two or more inches of soil may be perfectly pulverized by cultivation, that part of the soil which lies below is firmly packed into an impervious mass resembling vulcanized rubber or dried putty in consistency.

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[1] Hawaii Press Bulletin No. 29.

If soils of this character are carefully plowed, the fresh layer exposed to the air may soon disintegrate into granules and may be well pulverized by cultivation, while the previously pulverized layer now lying underneath soon returns to a compacted condition. If heavy rains occur the soil beneath takes on the puddled, impervious condition within a short time after plowing and thorough cultivation. During the prevalence of long periods of drought wide and deep cracks may form by the great shrinking of the colloidal matter in the soil. Cracks of this sort form to the depth of four feet or more and sometimes to a width of three or four inches unless careful cultivation is practiced. In soil which has become packed together into a solid mass neither air nor water can penetrate deeply or at least not rapidly enough for the purposes of plant growth. On this account great difficulty is experienced in irrigation. While the water-holding power of soils in Hawaii seems to be relatively high, yet the impervious nature of these soils when once compacted does not admit the penetration of water at a rapid enough rate to prevent the excessive loss of irrigation water from the surface by evaporation. It, therefore, comes about that in times of heavy rain the surface of the soil is over-saturated with water and superficial drainage must be provided to prevent erosion of the soil and also to prevent the exclusion of the air through over-saturation with water. Moreover, when drought occurs on the soils in question the rise of water from below takes place altogether too slowly to suit the demands of the plant and crops therefore suffer from drought to an undue extent.

One of the most serious consequences of the unfavorable physical condition of such soils is the fact that the nitrogen in

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the soils becomes unavailable. Except where good conditions for aeration are brought about, the amount of nitrogen in the form of either ammonia or nitrate is decidedly small. In some Hawaiian soils the chemical state of iron salts becomes unfavorable where proper aeration is impossible. Another injurious effect of improper aeration consists in the deterioration of the physical structure of the soil with special reference to its lack of granules.

From numerous observations made on soils in different localities under different crops it is obvious that success in farming depends to a large extent upon the maintenance of proper conditions for aeration and drainage. Otherwise, it seems impossible to hold the nitrogen in the soil in an available form or to bring about a suitable regulation of the water supply or distribution of air among the soil granules.

In attempts to overcome the troubles arising from the presence of a hardpan underneath the cultivated surface of Hawaiian soils, various devices have been used. In some of the pineapple fields good results have followed the use of surface ditches which carry off the surface water in times of excessive rain and thus prevent the soils from being packed together as firmly as would otherwise be the case. The cost of ordinary drain tiles, which have to be imported into Hawaii, is rather too great to allow their economic use on a large scale. There is apparently no clay in Hawaii which can be sucessfully used in making the ordinary red drain tiling. Recently some attention has been given to the use of cement tiles, and machinery for this purpose has been brought from the mainland. It is not yet known how expensive cement tiles will be. A few experiments have been made with fairly satisfactory results, using square redwood drains. Redwood will last at least for a number of years in the soil and the expense for preparing such drains is lower than the use of clay drain tiles even near the factory where they are made.

USE OF DYNAMITE.

On account of the difficulties which have been experienced in bringing about a proper drainage and aeration of Hawaiian soils, the station has for a number of years carried on experiments in the use of dynamite. The holes for receiving sticks of dynamite cannot be drilled in our heavy soils by the use of an ordinary soil auger. In fact, even soil samples cannot be taken by this means in the heaviest soils. The best method of making holes for dynamite consists in driving an iron bar into the soil by means of a heavy hammer. The sticks of dynamite used for this purpose are 1¼ inches in diameter by 8 inches in length. The iron bar need therefore not be more than 1½ inches in diameter and should be about 4 feet in length. A 16-pound hammer is sufficient to drive the bar to a depth of 2½ feet with a few vigorous blows. The bar can then be removed by tapping a few times on the side to set it loose from the surrounding soil. It may then be drawn out, using some care not to allow loose soil to fall into the hole. It is not practical to make holes for dynamite in this manner in soils which are excessively dry for the reason that too much loose earth will unavoidably fall into the hole when the bar is removed.

The proper distance apart at which the holes should be driven will depend somewhat on the nature of the land to be dynamited. In general it has been found that the cracks shattered in the soil by the dynamite explosion will meet across the space when the holes are driven 8 or 9 feet apart both ways. In preparing orchard land for planting, the holes will naturally be made at such distances as it is desired to plant the trees. A few preliminary tests will determine whether a half stick is sufficient to shatter the soil or whether a whole stick will be required. When the holes are made 9 feet apart we have generally found it best to use a whole stick. The holes should be firmly tamped all the way from the stick of dynamite to the surface of the ground since otherwise the explosion results in blowing a small quantity of soil high into the air and does not shatter the underlayers of the soil. If the holes are properly tamped the force of the explosion is exercised almost entirely at a considerable depth and shows little surface disturbance. Sometimes the surface layer of the soil is merely lifted a few feet immediately over the stick of dynamite and when this result is brought about the best effect is obtained from the dynamite. If the bar is driven to a depth of 2½ feet in heavy soils the explosion commonly results in shattering cracks in ordinary soils to a depth of about 4 feet and extending to about 5 feet in all directions around the charge.

Where considerable areas are to be prepared with dynamite the holes may be driven in rows 8 or 9 feet apart in the row, extending across the field. The dynamite is then placed in position with cap and fuse attached so as to reach just above the surface of the ground. By means of a gasolene blast torch one man can touch off 3 or 4 rows of dynamite fuse and keep out of harm's way.

For tree planting dynamite is confidently recommended as the best method of preparing the soil. Without the use of dynamite it is necessary to dig the hole at least 3 feet in diameter and to a depth of 2 feet. In heavy soils this will require the labor of a man for about one hour. If the hole thus prepared is filled with loose soil and the tree planted in it the tree may thrive for a year or two but the roots soon meet with the smooth and compacted surfaces at the edge of the hole through which the roots have great difficulty in penetrating. The tree is, in fact, in about the same situation as if it had been planted in a large tub. Where dynamite is used, however, cracks are formed in the soil to greater depths than would be reached by hand digging and to a distance of five or sometimes six feet on all sides, and the best conditions are thus furnished for the continued growth of the tree. The use of dynamite may, therefore, be recommended in planting papayas, avocados, mangos, bananas and other orchard fruits.

Little experience has been had in Hawaii in the use of dynamite for draining swampy places. In most localities where heavy rainfall occurs the soil is underlain with loose porous rock to such an extent that almost no running or standing water is to be seen. In a few cases, however, where small swamps were formed, dynamite was used with beneficial results, the water disappearing through the deep cracks formed by the explosion.

For most purposes considered in this connection a low grade dynamite is preferable to a high grade powder. In the experiments at the station a 25 per cent dynamite especially designed for plowing and soil preparation has been used. The explosion of this grade of dynamite is, of course, slower than that from higher grades and the force of the explosion is much more largely used up in shattering the lower layers of soil. The brands of high grade dynamite cause too much surface disturbance and do not produce so many nor so deep cracks in lower layers of the soil and sub-soil. As indicated above when the low grade dynamite is used and the holes properly tamped there should be little disturbance on the surface and the clods of earth should not be throw up more than a few feet.

According to the experiments carried on thus far, it appears that the cost of the dynamite, caps, fuse and labor amounts to about 3 cents per hole. If holes are driven 8x8 feet apart the cost per acre will therefore be $20.40; 9x9, $16.10; 10x10, $13.05; 20x20, $3.25. The last spacing named would be about the one used in planting orchard trees. In reference to the use of dynamite in farming operations, the phrase "plowing with dynamite" is frequently used. Even if the holes are driven not more than 8 feet apart both ways, the soil is not actually plowed but is simply loosened to a depth far below that of ordinary plowing. The ordinary plowing and harrowing operations must therefore be performed in addition to dynamiting.

The use of dynamite in preparing the soil is to be considered as in the nature of a special treatment to provide for deep drainage at relatively long intervals. It is impossible to say how long the deep cracks shattered by dynamite will remain effective in Hawaiian soils. In various localities in the Southern States where dynamiting has been practiced longest, it has been found that the effect of dynamiting persists for about 10 years. If the cost of dynamiting does not exceed $25 per acre it will thus be seen that this special method of preparation is a profitable investment from the standpoint of the physical condition brought about in the soil and the consequent increase in crop yield.

The formation of deep cracks in the soil is beneficial in improving the drainage possibilities. More water can be held in the soil by reason of this additional depth of soil spaces and the movement of water takes place more rapidly both downward during rains and upward in time of drought. In some cases an actual pocket is formed by the explosion of the stick of dynamite, while from this pocket numerous cracks radiate in various directions. So far as observations have been made, the beneficial effects from the use of dynamite are apparent in the growth of trees and other crops. As already stated, however, these observations have not been carried on for more than three or four years on Hawaiian soils.

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Issued February 8, 1913.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 39.

The Extraction and Use of Kukui Oil.

By
E. V. WILCOX
and
ALICE R. THOMPSON.

COMMERCIAL IMPORTANCE OF KUKUI OIL.

BY E. V. WILCOX.

Kukui, (Aleurites triloba, or A. moluccana), is generally distributed throughout Polynesia, Malaysia, Philippines, Society Islands, India, Java, Australia, Ceylon, Bengal, Assam, China, Tahiti and Hawaii. It has been introduced into the West Indies, Brazil, Florida and elsewhere. The tree has wide-spreading branches, attains a height of 40 to 60 feet, and is characterized by large, irregularly lobed leaves of a pale green color, and nuts about two inches in diameter containing one or two seeds. In Hawaii kukui is common on all the islands, being the dominant native tree of the lower mountain zone and easily recognizable at a distance by the pale color of its leaves.

The oil expressed from the kernel of the nut is known in different countries as kukui oil, country walnut oil, kekune oil, artists' oil, Bankul oil, Eboc oil, candle nut oil, Spanish walnut oil, Belgaum oil, etc. The oil has found use for a variety of purposes. The Hawaiians strung the nuts together on sticks and used them for lighting their houses. The natural candles thus produced gave rise to the name candle-nut. In an examination by the Imperial Institute it was found that "the oil belongs to the class of drying oils typified by linseed oil, and would be suitable for the manufacture of soft soap and in the preparation of oil-varnishes, paints, linoleum and other similar purposes".[1]

Guthrie and Ramsay state: "It is a drying oil and is used in the arts for the same purposes as linseed oil, and for burning. Its drying power is quite as high as that of linseed oil, and it may be used for all purposes for which the latter is used, namely in the manufacture of oil-colors, lacquers, and varnishes, and for soap making. It is used medicinally as a plaster, and as an article of diet—as olive oil is used."[2] Both the oil and the cake are cathartic and have been used for the purpose in medicine. The cathartic effect is reduced by subjecting the nuts to heat. Kukui oil has been used in China for oiling paper, as China wood oil is used. As a wood-preservative kukui oil has given good results in China and in Hawaii both on the hulls of sailing vessels and on buildings. Thrum, referring to kukui oil in Hawaii says: "The last use, to our knowledge, made of it in house painting here was at the construction of the Judd building, about 1855, by R. Gilliland, who is said to have made the statement that it was good for fifteen or twenty years".[3]

As is well known to the old residents of Hawaii, there was once an industry of quite respectable proportions in kukui oil, exported from Hawaii. The exportation amounted to as much as 8,000 to 10,000 gallons of oil per year, the greatest production of kukui oil having occurred from 1840 to 1850. The oil even at that date was valued at 50 cents per gallon. It is reported that in 1857 a native woman in Palolo valley expressed kukui oil at the rate of 140 gallons per month with a crude hand-made lever press, the nuts having been previously roasted or boiled in oil to facilitate extraction.

It is quite impossible to estimate even approximately the quantity of kukui nuts which could be collected annually in Hawaii. Every one knows that the ground under kukui trees is literally covered with nuts of which few are used for any purpose at present, except in very small quantities in the preparation of a native relish and occasionally for fuel. According to our experiments in the laboratory it would require 210 tons of nuts to produce 10,000 gallons of oil weighing 7.36 pounds per gallon or 73,600 pounds in all.

With regard to the total area of kukui in Hawaii we have obtained the estimates of various individuals who are personally familiar with forest conditions in Hawaii. Their estimates range from 10,000 to 40,000 acres. We may probably assume 15,000 acres as a safe estimate. At the rate of 80 trees per acre and

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1. Bull. Imp. Inst. 5 (1907) P. 136.
2. Agric. Gaz. N. S. Wales 17 (1906) P. 859.
3. Hawaiian Annual 1893 P. 107.

200 pounds of nuts per tree, there would be a yield of eight tons of nuts per acre. It has been found that algaroba yields from two to fourteen tons of beans per acre. A good stand of kukui will give a larger product per acre, and a conservative estimate would be five tons of nuts. On 15,000 acres the annual crop of nuts would thus be 75,000 tons. If we assume that not more than 10,000 acres of this area are readily accessible the yield would be 50,000 tons, which would produce 2,375,000 gallons of oil. In 1911 the importation of Chinese wood oil into the United States amounted to 5,800,000 gallons, and a buyer in New York stated that his firm alone could have used an additional 500,000 gallons.

Chinese wood oil obtained from the nuts of *Aleurites cordata* and *A. fordii* has been imported into Europe for the last twenty-five years and into the United States for fifteen years. It finds its chief use in the manufacture of varnish, for which it is more and more in demand. The oil has a specific gravity of .94 and dries more quickly than any other known oil. In this regard kukui oil stands between Chinese wood oil and linseed oil. Chinese wood oil is sold by the pound and the price during the past fifteen years has ranged between 6½ and 12½ cents, being 9 cents in December, 1912. In experiments at this Station the kernels of fresh nuts contained 27.1 per cent of oil, the whole nut being 14.1 per cent oil. The tree has been introduced into Hawaii and the southern states of the mainland, but no estimates can be made at present on the possible yield of oil.

Kukui oil has been shipped from various islands of the Pacific to the United States for the past 75 years for use in making soap, paint, varnish and artists oil. The market price is the same or slightly higher than that of linseed oil and varies with the price of the latter. Kukui oil can replace linseed oil for all purposes, but dries more quickly. According to Andés it dries four hours sooner than linseed oil.[1]

The kukui is a tree which is practically free from serious insect pests or fungous diseases, and bears an annual crop of nuts without fail. The nuts mature in summer during school vacation, when children as well as men and women can engage in collecting them. The difficulties in collecting the crop are no greater than those which have been met and overcome in the algaroba meal industry. To secure a large part of the crop at a central oil mill it is merely necessary to offer a reasonable price per hundred pounds for the nuts.

It will probably require one season of practical experience to arrive at a working basis for collecting the nuts. We have attempted to gather data which would give a hint of the price which can be paid for the nuts, a price which will give an attractive wage to the collector and leave a reasonable profit to the oil mill. From our experiments it appears easy for a man, woman or child to pick up 500 pounds of nuts per day. The nuts are of course to be gathered free from the soft outside husk. Only an extremely small percentage of the nuts spoil or turn rancid even after lying two years on the ground. The spoiled nuts float in water and may thus be easily separated from the sound ones. At 30 cents per 100 pounds the laborer would receive $1.50 for 500 pounds, a day's work. The average oil content of the meat or kernel is 65 per cent. The kernel equals 30 per cent of the weight of the nut. About 19.5 per cent of the nut is therefore oil. In the Sunda Isles, where kukui oil is an important article of export, experiments have shown that 90 per cent of the oil is obtained by commercial methods through the use of presses.[1] The oil recoverable by commercial methods would thus amount to 17.5 per cent of the weight of the nuts. From 100 pounds of nuts 17.5 pounds of oil would be obtained, or a value of $1.75 at 10 cents per pound. During the fiscal year ending June 30, 1911, nearly 50,000 gallons of linseed oil was imported into Hawaii, valued at $49,127. Kukui oil would make this importation unnecessary.

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[1] **Vegetable fats and oils 1902 pp. 174-176.**

Langeron found that 100 Kg. of kukui nuts contained 33 Kg. of knernels; that 100 Kg. of kernels yielded 66 liters of oil; and that 100 liters of oil weighed 91 Kg. In another test 224 pounds of kernels yielded 50 quarts of oil. Frick[2] at a meeting of the Royal Hawaiian Agricultural Society exhibited six vials of kukui oil prepared in different ways and possessing different colors and properties. He stated that the oil could be sold with profit at 50 cents per gallon.

Kukui oil may be obtained by grinding the kernels and applying pressure with or without previous roasting of the nuts. The color of the oil is lighter if no heat is used, but the oil is more easily expressed after heating. Mr. W. A. Anderson of Hana, Maui, ran a quantity of nuts through the steel rollers of a rubber mangler. The resulting oil has a wine color, derived from the husk of the nut. The oil is naturally of a light straw color. The most economic and efficient method of grinding the nuts and the most suitable kind of press to be used, will naturally, have to be determined by the manager or engineer of the company that may engage in manufacturing kukui oil. Apparently the oil can not be obtained by boiling the ground nuts in water, for the oil is thereby completely emulsified and can not

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1. Semler, Die tropische Agrikultur, Vol. 2, P. 517.
2. Trans. Roy. Haw. Agric. Soc. 2 (1856) pp. 101-103.

be set free by the use of a centrifuge. The oil has been successfully extracted, however, by boiling the nuts in oil.

A miscroscopic examination of the kernel of a kukui nut shows the usual structure of oil seeds, such as the castor bean. The cells contain no free water or cell sap, but are filled with free oil and typical aleurone grains. The latter account for the high percentage of protein in the press cake. Occasionally clusters of crystals of calcium oxalate are observed in the cell structure of the kernels. No trace of starch could be found even in immature nuts. Iodine also failed to give the starch reaction in the press-cake.

When we consider the constantly increasing demand for oils suitable for use in making paints, varnish and soap, as well as for other purposes, it seems high time that a company were organized to utilize the large quantity of kukui nuts which annually go to waste in Hawaii. Not only is the oil a valuable product, demanded by the paint and varnish trade, but the press-cake is unusually rich in nitrogen, phosphoric acid and potash. It, therefore, has high value as a fertilizer. The chemical investigations reported in this bulletin were undertaken to furnish a basis upon which an industry in producing kukui oil could be established. Among firms which are interested as possible buyers of kukui oil we may mention Edward Hill's Son & Co., 64 Wall St., New York City. The Glidden Varnish Co., Cleveland, Ohio, and A. M. Parks Co., Bourse Building, Philadelphia.

CHEMISTRY OF KUKUI OIL

BY ALICE R. THOMPSON.

Kukui oil, commonly known as candle nut oil, belongs to the class of drying oils, valuable therefore as a paint and varnish oil. It is also used for soap making and is a good illuminating oil. It is produced in large quantities in Australia, China, New Zealand and the Fiji Islands[1] and is exported to America and Europe in ever increasing shipments.

When extracted from the crushed kernel by ether or petroleum, the oil is light yellow in color, with a specific gravity of 0.92. When expressed, the oil may be dark colored due to impurities. It dries in thin films on standing several days.

At this Station, a sample of oil was extracted by gasoline from the crushed kernels; the gasoline removed by evaporation and an analysis made on the oil to determine its chemical and physical properties. The values are as follows:

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[1] Bull. Imp. Inst. 1907, 5, P. 135, 136.

Specific Gravity..........	.92 at 15.5° C.
Saponification Value	179.1
Iodin Number	155.5
Hehner Value	89.9
Soluble Acids	1.71
Reichert Meissl Number .	2.82

The fatty acids congealed to a pasty mass between 18° and 20° C. The oil itself was still fluid at—3° C. Fendler[2] found the congealing point of candle nut oil to be —15° C. The oil was soluble in ether, petroleum ether and slightly soluble in alcohol. Concentrated sulphuric acid colored it dark brown.

The drying property of the oil is indicated by the high Iodin Value. Linseed oil which is a fine drying oil has an Iodin Value of 170-181[3].

A sample of oil expressed from kukui nut was sent by Mr. Anderson to this laboratory. The oil was in a crude state, containing suspended matter, and had a dark red color. This oil had the following values:

Specific Gravity	.92 at 15.5° C.
Saponification Value	190.2
Iodin Number..........	164.2

In the following table are given the values found by chemists in the oil of Aleurites moluccana obtained in other parts of the world.

	1	2	3	4	5
Specific Gravity at 15° C.	.925.	920- .926	.925	.925	.924
Acid Value	1.72			.97	0.5
Saponification Value...	204.2	184 - 187.4	192.6	194.8	189.5
Iodin Value	139.7	136.3-139.3	163.7	114.2	152.8
Hehner Value	96.4		95.5		95.2
Volatile Acids	1.98			1.2	
Titer	17.8				
Butyro-refractometer	....	76-75.5(15° C)	76(25° C		

1. Imperial Institute, Bull. of the Imperial Inst. Vol. V (1907) p 135-136.
2. De Negri, Jour. Soc. Chem. Ind. 20 (1901) p 909.
3. Lewkowitsch, Jour. Soc. Chem. Ind. 20 (1901) p. 909.
4. G. Fendler, Jour. Soc. Chem. Ind. 23 (1904) p. 613.
5. Kassler, Jour. Soc. Chem. Ind. 22 (1903) p 639.

The values vary to some extent in these analyses; nevertheless, the general characteristic of high Iodin Value and Saponification extends throughout.

CONSTITUENTS OF THE KUKUI KERNEL.

Several samples of nuts were obtained and the fat especially determined in the kernels. The fat content appears to vary but a few per cent in the kernels of nuts a year old or fresh. The fresh nuts naturally contain more moisture.

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[2] Jour. Soc. Chem. Ind. 23 (1907) P 613.

[3] Commercial Org. Analysis—Allen, Vol. II, Pt. 1, p. 97.

	1 year old nuts. per cent.	Fresh nuts. per cent.	Immature nuts p. c.
Moisture	3.55	7.14	13.39
Fat	65.00	66.25	56.7
Ash	3.56	3.05	
Protein	18.75	19.88	
Fiber	2.14	1.39	
Nitrogen free extract by difference	7.00	2.29	
	100.00	100.00	

The fiber and the ash are very low, the principal constituents being fat and protein. It is of interest to note in this oil seed the small percentage of hydrolyzable carbohydrates (only 1.40 per cent by analysis). A qualitative test showed the absence of starch in the kernel. The quantity of fat, if calculated to the water free basis is quite constant in the three samples.

Analyses made of the kernels of this same nut, Aleurites moluccana, by various chemists are given in the table below.

	1 Per Cent	2 Per Cent.
Water	5.00	8.23
Oil	62.175	59.93
Protein	22.653	8.04
Nitrogen free extract	6.827	17.62
Ash	3.345	3.56
Fiber	....	2.62
	100.00	100.00

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1. H. Semler—Die Tropische Agrikultur Vol. 2, p 515.
2. N. S. Wales—Agri. Gazette 17 (1906) p 859.

G. de Negri[1] extracted 62.25 per cent fat by ether extraction. At the Imperial Institute, 60.8 per cent oil was extracted from the kernels by means of light petroleum. In all the analyses, the fat and protein content are high. The mineral constituents of the kernel were also determined as shown in the following table:

Mn_3O_4	.03 per cent
CaO	.17 " "
MgO	.60 " "
P_2O_5	1.59 " "
K_2O	.75 " "

On extraction of the oil these constituents[2] increase in proportion to the dry matter. The residue contains, therefore, large amounts of phosphoric acid potash and nitrogen, all valuable as fertilizing ingredients. Analysis of the residue of ground up kernels extracted with ether for two days is as follows:

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[1] Jour. Soc. Chem. Ind. 17 (1898) p 931.
[2] Bull. Imp. Inst. Local Cit.

Moisture	2.42	per cent
P_2O_5	2.79	" "
K_2O	2.77	" "
Protein	53.75	" "

Press cake obtained commercially by expressing the oil from kukui nuts would compare favorably with the residue, as most of the oil can be expressed. According to an article in the Agricultural Gazette[1] 55 per cent oil can be obtained from kernels containing 60 per cent. Analyses of press cake made elsewhere shows it to be valuable as a fertilizer.

ANALYSES OF PRESS CAKE.

	1 Per Cent	2 Per cent.
Oil	8.8	5.5
Moisture	10.00	10.25
Ash	8.28	
Protein	46.16	47.81
Fiber	1.47	
P_2O_5	4.39	3.68
K_2O	1.95	1.53
Mg & Ca		7.19

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1. Lewkowitsch Jour. Soc. Chem. Ind. 20 (1901) p 909.
2. H. Semler—Die Tropische Agrik. Vol. 2 p 515.

Press cake cannot be used as a fodder in spite of its apparent food value as it has a poisonous effect upon stock.[1]

The proportions of fat to kernel and whole nut were determined in several samples. In a sample one year old in which the fleshy husk that covers the shell when the nut is green, had decayed away, the kernel weighed 31.5 per cent of the hard nut. As the fat content of the kernel was 65 per cent, the fat content of the nut minus the husk, averaged about 20 per cent.

In a sample of fresh nuts, the kernel was 29.3 per cent of the nut minus the husk and 12.1 per cent of the nut with the husk on. The fat content of the kernel was about 66 per cent. It was therefore about 8 per cent of the nut with the husk on and about 19.4 per cent of the hard nut minus the husk.

In another sample of fresh nuts, the kernel was 12 per cent of the nut with the husk on and 30.4 per cent of the hard nut minus the husk. The kernel contained about 57 per cent fat. The fat content of the whole was therefore about 7 per cent and of the nut minus the husk, about 17 per cent.

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[1] Agric. Gaz. N. S. W.—17 (1906) p 859.

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HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN No. 40.

Silos, Silage and Silage Crops for Hawaii.

By

C. K. McCLELLAND, Agronomist.

It has been the purpose of ranch owners and managers in Hawaii during recent years to put the business of beef-production upon a sound and scientific basis. To accomplish this different methods were tried. Some have divided their grazing areas into paddocks so that when any one area becomes closely cropped it is possible to allow it to rest and recuperate. Tame grasses have been introduced and planted upon many of the ranches with varying degrees of success. Improved pure-bred stock are in use for breeding, so that the quality of the produce is being gradually improved.

Yet when all this has been done there has been found to be something still lacking; there is still a weak spot in the system through which at times irreparable loss has occurred. The lands in use for ranching purposes are, necessarily, those unsuitable for the production of well paying cultivated crops. Because of high elevation, of rocky surface, of steepness, or of dry conditions, these lands are not arable and are of value only for grazing. Yet within the boundaries of each ranch there may be certain areas which, though limited in extent, are suitable for the production of tame forage at certain times of the year.

The weak spot in the system as heretofore managed has been that there would be plenty of grass and forage at certain seasons when rains had occurred, but during the dry seasons and years, there would be great scarceness of feed and often a loss of many head of cattle.

To tide over this period of scarcity has been the problem of the ranchmen. There seems to be but two solutions to the problem: namely, prickly pear and silos. Drought resistant grasses have not been able to accomplish desired results. Although able to hold on, these grasses do not make sufficient forage during periods of drought. It is the purpose here to discuss only the question of silos and the use of silage as a means of overcoming this loss during dry seasons.

Silage is partly fermented green feed. The feed is placed in airtight pits or structures when in the green state and containing 75-85 per cent of moisture. The purpose of the silo is to retain the moisture and exclude the air. When placed in the silo the feed begins to ferment and get hot. Lactic acid and other bacteria, and various yeasts are concerned in this heating and fermentation. At the end of about 36 hours the temperature is quite high. However, complete fermentation and decay is prevented by the exclusion of the air, and such a result will be found at any point where air chances to enter. The biochemical changes are completed in about 12 days.

Silage is one of the most valuable of feeds in that it is succulent and nourishing, and available in winter or during droughts when other succulent feeds are unobtainable. It is very palatable, being relished by all species of domestic animals as soon as accustomed to the feed. The composition of silage depends largely upon the material and mixtures used in filling and the stage of maturity at which they are cut.

Composition of Silage.[1]

	Water %	Ash %	Crude Protein %	Fibre %	Nitrogen free extract %	Fat %
Corn, immature	79.1	1.4	1.7	6.	11.	.8
Corn	73.6	2.1	2.7	7.8	12.9	.9
Corn, ears removed	73.7	1.6	2.2	6.5	15.1	.9
Sorghum	76.1	1.1	.8	6.4	15.3	.3
Soybean	74.2	2.8	4.1	9.7	6.9	2.2
Cowpea	79.3	2.9	2.7	6.	7.6	1.5
Corn and Soybean	76.	2.4	2.5	7.2	11.1	.8
Teosinte	66.8	4.	2.5	12.3	13.6	.8
Prickly pear[2]	94.63	1.12	.71	.57	3.19	.08

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1. Henry's Feeds and Feeding.
2. Haw. Agr. Expt. Sta. Bul. 13.

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It has also a high percentage of digestibility, the figures as given in the Annual Report of the Ontario Station for 1906 being as follows: Protein, 55 per cent; fat, 61 per cent; nitrogen free extract, 74 per cent; and crude fiber, 74 per cent.

It has a laxative effect when fed in large amounts, but some dry feed usually counteracts this action. Cases are on record where moldy silage has caused the death of horses with symptoms similar to those of cerebro-spinal meningitis. While of great value in any ration as stated below, silage can not replace grain feed entirely. In New Hampshire, tests showed that the milk flow was decreased when, beyond a certain limit, the grain was reduced and the silage increased in the feed.

Silos and silage were, in the first days of more common use, thought to be of advantage only upon dairy farms. But later tests have shown that silage is of value for feeding horses, mules, sheep, lambs, beef cattle and poultry.

The sum and substance of nearly all experiments has been that silage increased the gain or rate of gain while at the same time reducing the cost of production. The cost of butter in a herd upon dry feed (in Miss.) was 29.9 cents a pound, while with silage the cost was reduced to 20.9 cents. In Iowa the cost per pound gain on lambs fed mangels and beets was 6.82 cents, while with silage the cost was 5.9 cents. In Texas, in a comparison between silage with a small amount of hay and cotton seed hulls in feeding steers, the cost per 100 pounds of gain was reduced with silage from $10.04 to $7.32, while the amount or rate of gain was nearly identical. In Indiana, in fattening lambs, the addition of silage to a ration of clover and shelled corn did not affect the rate of gain but slightly reduced the cost. At the South Dakota Station, steers fed on silage as a maintenance ration were consuming 70 pounds daily at the end of the trial. They increased in weight but were not fat. In another experiment mangels proved superior to silage in making gains. Numbers of experiments have been made in various places and in comparison with all kinds of roughage, with the result usually in favor of the silage.

The reduced cost of production is due in some cases to a reduction in the amount of grain consumed, and more frequently to the greater gains made and to the lesser cost of the silage, which is figured at $3.00 to $4.00 a ton.

THE CAPACITY OF SILOS AND WHAT SIZE TO BUILD.

The following table gives the approximate capacity of silos of various dimensions and average weights per cubic foot of silage at various depths. To find the number of tons in a silo, the contents should be figured from the depth of silage after settling, rather than from the depth of the silo.

Capacities of Silos and Weight per Cubic Foot.

Depth of silage	Inside diameter in feet							Average Weight per cu. ft.
	12	14	16	18	20	22	24	
20 Feet	....	....	66	84	104	126	150	33.3
22 Feet	....	....	76	96	119	144	172	34.6
25 Feet	....	....	89	116	143	173	206	36.5
28 Feet	61	83	108	136	168	204	243	38.4
30 Feet	67	91	119	151	186	225	268	39.6
32 Feet	74	100	135	165	204	247	294	40.7
36 Feet	87	118	155	196	243	289	348	42.8
40 Feet	101	138	180	229	280	338	407	45.
44 Feet	....	....	212	264	320	397	467	48.
50 Feet	....	....	251	318	382	470	565	50.
Wt. of 5″	1885	2575	3350	4250	5250	6100	7535	8850

If one well understands the principles of ensiling it will be seen that deep silos are preferable to shallow ones. The average weight per cubic foot increases with the depth of the silage. A silo should be 2 to 3 times as deep as broad, and as now constructed they average about 2½.

It is necessary to feed off a certain amount each day to prevent loss by molding, and one should calculate from this and from the number of animals he has what size of silo will fill his requirements. For simplicity the average weight of a cubic foot of silage is figured at 40 pounds. If a man has 40 cows and wishes to feed each 30 pounds daily and must feed off 2 inches daily, the problem works out like this:

Amount fed = 1200 lbs. or 30 cu. ft.
30 cu. ft. divided by 2″ daily = 180 sq. ft.
180 sq. ft. = the surface area of the proposed silo.
The square root of (180÷.7854)=15 ft.
The diameter of the silo wanted equals 15 feet.
If 2″ are fed off daily and the silage is 30 ft. deep, the feed will last about 180 days.

If, in Hawaii, 5 inches must be fed off daily, either one must have narrow silos or larger herds of cattle. In the above example if 5″ be substituted for 2″ the diameter of the silo required will be found to be less than 10 feet. If, however, a man has 300 head and wishes to feed 25 pounds daily while removing 5″, the problem works out thus:

Amount fed = 7500 pounds or 187.5 cu. ft.

187.5 cu. ft. divided by 5″ = 450 sq. ft. or the surface area of silage.

The square root of (450 divided by .7854) = approximately 24 feet = diameter of silo wanted.

From these examples, the reader will be able to calculate the size of silo suited to his particular needs.

Acreage.

The acreage to plant to fill a given size of silo may be determined only after some records have been kept for several years. To divide the capacity of the silo by the average yield per acre and then add 40 or 50 per cent for allowance for dry season, would seem to be a good rule. If any excess seems likely, some may be fed out green as a soiling crop.

The yield of corn should be from 7 to 10 or 11 tons per acre, in order to prove profitable.

Construction of Silos.

The principles upon which silo construction is based have been mentioned in a preceding paragraph. The primary objects of a silo are to exclude the air from the silage and to retain the moisture already found there, or much of it. Other considerations are secondary, yet kind and quality of the building material, durability, cost of construction and maintenance, whether fireproof or not, and appearance should be considered.

For temporary purposes, cheap silos may be satisfactory, but in the long run the more solid structures will prove to be the cheaper. The cost of repairs and often a loss in spoiled silage make cheap silos dear at any price. However, any material which accomplishes the primary objects above mentioned may be used. It must be remembered that strong walls are absolutely necessary for best results. The weight of the silage is supported by the bottom of the silo at the ground, but the lateral pressure when silage is settling must be borne by the walls, and the latter must not warp or bend else air may be admitted. That the lateral pressure in time subsides is proven by the fact that in many cases of fire, the structure of the silo has been destroyed, leaving a circular mass of silage 20 to 30 feet high which retained its shape until some time later, when the silage became spoiled because of exposure to the air.

Prof. King of Wisconsin found that the pressure increased 11 pounds per square foot for each foot in depth, i. e., at 10 feet from the surface the lateral pressure was 110 pounds per square foot; at 20 feet it was 220 pounds; at 30 feet it was

330 pounds, and so on. This explains why it is necessary and important to have proper strength in the walls and especially near the bottom. The walls must be straight and smooth to facilitate settling of the silage and to allow this without the formation of air pockets at the sides. When a silo is filled rapidly, the mass will settle one-fifth or one-sixth of the height in the next four or five days, after which the silo may be again filled to the top. Again, walls of some strength and weight are necessary to resist the wind when they are empty and dry. Many of the cheaply constructed silos have thus been racked out of shape, ruined for the intended purposes, or completely destroyed. Durability depends upon the durability of the materials used and upon the solidity or rigidity of the structure.

The Foundation.[*] As in all structures, a firm foundation is necessary—even more necessary, since in a leaning silo there is a tendency for the silage to settle away from one wall.

The thickness of wall depends upon the kind of silo erected. The weight of the superstructure rests upon the foundation, and a larger foundation would be necessary for stone, brick or concrete than for building blocks, frame or stave silos. The width of the "footing" course varies for the same reason.

The walls should extend one foot above the surface and three to four feet below the surface to solid earth, where variations in moisture found at the surface may be avoided. If soil is porous or if in dry regions, probably no drainage will be necessary. Otherwise a tile underdrain, imbedded in gravel or coarse sand, should be placed under the foundation walls and floor of the silo. This drain may open into the floor of the silo, but if so the opening should be well plugged before filling.

Materials. Hard burned brick or stone, laid in cement, or concrete should be used. To lay the stone and pour thin cement mortar in to fill the crevices has been found to be a faulty method. Either lay the wall regularly in a thick mortar or construct a form and put in the mortar first and wet sand and rock afterwards, well tamping the mixutre. The best results, however, can be obtained only when true concrete is regularly made and mixed upon a mixing board, or in a mortar box, or in a machine, before placing it in the form. If the soil is used for one side of the form, it would be well to use tarred paper by it to prevent loss of moisture from the concrete or the entrance of any clay particles into the mixture. Wire, iron rods or woven fencing may be used for reinforcement.

Upon dry clay a floor in a silo is not necessary; with porous

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[*] **See Plate I-E.**

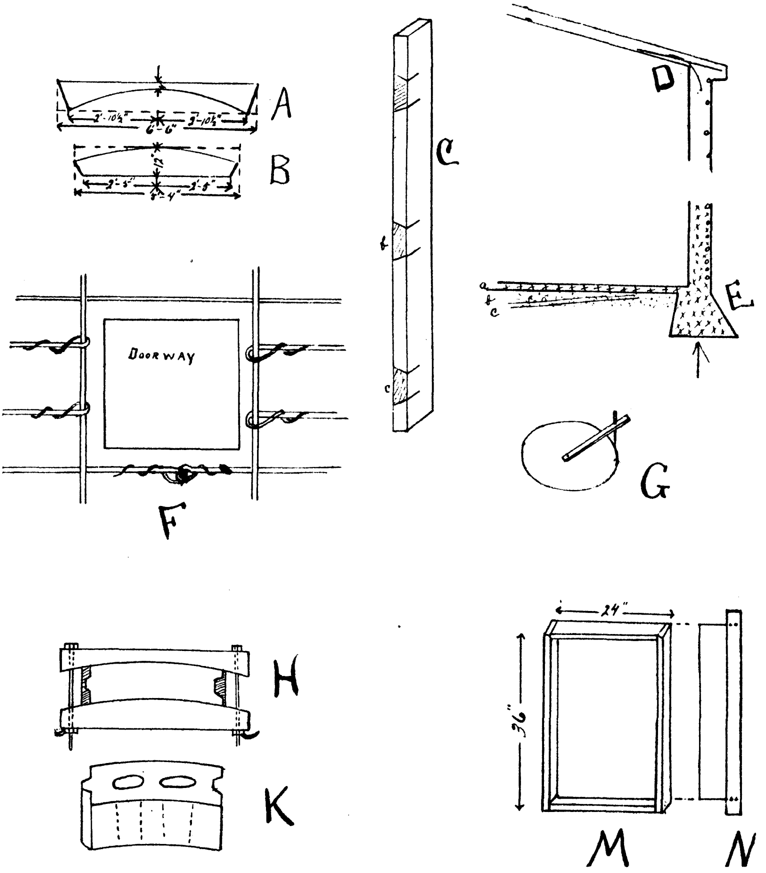

PLATE 1—from various sources.

A shows section of outer form for concrete silo cut from 2"x12"x6'-6".
B shows section of inner form for concrete silo cut from 2"x12"x5'-4".
C shows how to start the saw in one stave to make a beveled door for a stave silo; the larger opening should be upon the inside.
D shows reinforced union of roof and wall in a concrete silo, and cornice.
E shows foundation for any silo with a section of wall and reinforcing in a concrete silo. "a" is the floor; "b" is gravelly sand; "c" is tile drain.
F shows one method of reinforcing about the doors in concrete silos.
G shows method of marking circle for foundation or for making forms.
H shows side pieces of form for making cement blocks.
The bottom boards and wooden cores are not shown.
K shows a hollow cement block as made in form "H."
M shows section of form for doorway of concrete silo. For 6 inch walls use 2"x6" material and 2"x8" material for 8 inch walls.
Over M is placed another similar box 28"x40" made of 2x2 material.
N shows a side view of the completed form. When placed in the wall, the side having the 2"x2" rim about it is placed upon the inside.

or wet soil it is, and a thin floor is almost always made. One may use less cement in the mixture for the floors. In foundations for wood structures, the walls should extend at least a foot above the surface and a sill with anchor bolts or heavy spikes, imbedded at the surface to which the studs may be securely toenailed. Pieces 2"x4"x2' may be used. The anchor bolts or spikes extend at least three inches into the foundation below the sill. Long anchor bolts should be inserted back or outside of where staves will come in foundations for stave silos.

The Roof. The roof of a silo is as unimportant as the floor —in other words, it may or may not be necessary. It is necessary in cold climates to prevent the freezing of the silage and in wet regions to exclude heavy rains. Light rains, however, do no damage. The top of the silage is always exposed to the air and air-tightness of the roof is of no avail. The roof adds to the appearance and prevents trash from blowing in, to a slight extent.

A plate may be nailed to the top of the studs or staves, but in masonry silos a plate must be imbedded as described for sills of wood structures. If cement roof is to be put on, plates are unnecessary. Reinforcement connects wall and roof as in Plate I-D. The roof may be conical or pyramidal, with sides sloping toward the highest point at the center; or gable roofs or shed roofs with but one slope may be built. The latter is much simpler and cheaper, but might be more easily lifted by the wind unless securely anchored.

Materials. With shed or gable roof, galvanized iron, tin, roofing paper, cement, slate or shingles may be used. With conical or pyramidal roofs, cement, tin, slate, shingles or possibly paper can be used. In many places in Hawaii it might be convenient and economical to construct merely a framework for a roof and then over this use a canvas curtain which can be taken down after the heavy rains when a roof is no longer necessary. However, after the removal of scaffolding, the placing and removal of the canvas would be attended with some difficulty and danger. Metal lath and cement roofs have been used in some cases and are satisfactory.

For filling the silo an opening must be left or built into the roof. Either a trap door or a dormer window will answer the purpose.

Door for the Silo. The doors should be located in a vertical line for convenience. Some have placed them upon different sides, thinking that the structure is too much weakened when all are in line. Doors at 4 feet apart or 6 to 8 feet from center to center, will be numerous enough for convenience in feeding. Continuous doors are in use, mostly in some of the "patented" silos. These are put in as silo is filled and removed as it is emptied. The slight advantage they give is that entrance to the silo is more easily made through them and some labor in getting out the silage is avoided.

A chute should be built by the doors down which the silage is thrown in getting out the feed. A cart or wagon may be backed under the chute and the silage loaded without rehandling. A ladder may be built up along one side of the inside of the chute. In its absence portable ladders may be used; or a ladder may be made only between doors; or, in the concrete silo, rods may be imbedded in the concrete which serve the purpose.

The Kind of Silo. There are two kinds of silos, according to placement above or below the surface of the ground. The pit silo was the original silo used in Europe. It is simple, but laborious to construct; requires no foundation or reinforcing or elevation of material when filling, but does necessitate lifting the feed when emptying, and as the larger proportion, by far, of the silage is at the bottom, the work becomes tedious before the silage is all fed out.

Plastering the sides and bottom with a half inch of cement plaster is all that is necessary after the excavation is made; *i. e.,* where moisture is not excessive and cement will adhere to the walls. In some places a single brick wall is laid up and plastered. A thin concrete wall could also be easily made.

The elevated silo has been found more satisfactory because of the ease in handling the silage. Power machinery is necessary to cut the corn or other feeds used and it takes but little extra power to lift the cut feed to the top of the silo. The placing of improved machines and power for the few days necessary to fill this form of silo, in a comparison with the extra work by hand, or by windlass, or by horse power, for the 150 or 180 days necessary to feed out the silage, results greatly in favor of the use of power for a few days and of the elevated silo.

So great is the objection to lifting silage by hand that doors are made continuous or at intervals of but a few feet from each other, and the bottom is excavated to only a depth of about three feet or four feet below where the first door is to be made, so that never does the silage have to be pitched over four feet high.

Of the elevated type there are many different forms, according to the materials used and the methods of construction.

The Stave Silo. The simplest and cheapest forms are known as stave silos. If well built, the silage in them keeps well. A temporary silo has been constructed very quickly and cheaply by using plain staves without bevel or tongue and groove, and binding these with woven wire fencing drawn tight with stretchers. Such a silo, however, is not durable, since there is nothing to prevent the warping or bending of the staves. The Dairy Division of the Bureau of Animal Industry, in B. A. I. Circular No. 136, recommends plain staves spiked together. Near each end and in a few places along the length of each stave (except where the doors are to be cut out) holes are bored straight into the edge of each stave. When erected, spikes are driven from a certain stave to the adjoining one, being started in these holes and driven home with a drift pin. Prof. Krauss at Kamehameha Schools (Vol. III, Hawaiian Forester) used a common water tank, inverting every other stave so that diameter of the silo at the top would not be reduced below that at the bottom as is the case with many of our stave water tanks.

The staves should be beveled, tongued and grooved; the hoops should be of flat or preferably of round iron and of sufficient number; and then, if well anchored or guyed, and the hoops kept tight, the stave silo will endure and do good work for many years. Being light in weight, anchoring and guying are necessary to avoid damage by wind when they are empty. The staves must be straight-grained heart wood, without knots or windshakes. Redwood, cypress or Oregon fir are durable, but the first named shrinks and swells less when empty or filled. Staves if possible should be of full length, planed on the inside at least to better allow the settling. If to be painted on outside, both sides should be planed. If unable to secure staves of full length, shorter ones may be toenailed firmly together. Steel or galvanized iron "splines" are often used to make the union more perfect. A groove is sawed into the ends of the two staves to be spliced and the spline fitted into these grooves when putting up the staves. The spline should be slightly wider than the staves so as to mesh into adjoining staves. For a 30 foot silo 20 foot staves may be secured and some cut into 10 foot lengths, and then a short piece used first at the top and then at the bottom so as to "break joints," or pieces 14 feet and 16 feet in length may be similarly used. For a 36 foot silo, pieces 16 feet and 20 feet may be used, and so on.

For narrow silos, 12 feet or less in diameter, staves 2"x4" should be used, and for those 14 feet or more in diameter, staves 2"x6" are better; in very large structures it is possible

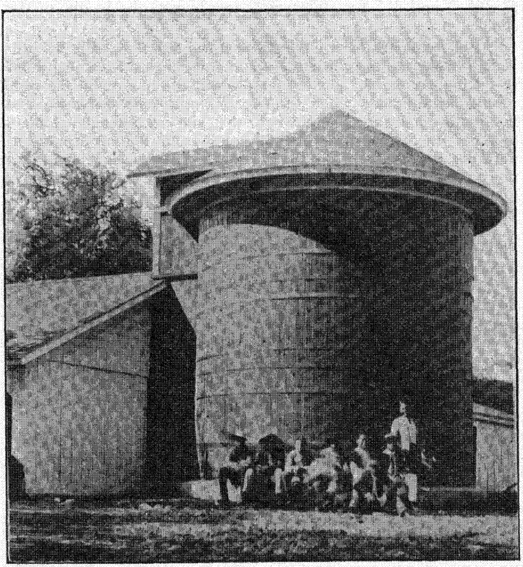

PLATE 2—
Stave silo at Kamehameha Schools—made from water tank staves.

that staves 2"x8" even could be used to advantage. The hoops should be of 5/8" round iron preferably, since band iron rusts out more quickly and the staves rot beneath the bands. The rods are more easily handled if in short sections of from 12 to 16 feet in length and should be well threaded at the ends. The lugs should be of cast iron, since the use of wooden lugs results in rotting the wood of the stave and lug, beneath the lug. Because of the lateral pressure, as previously explained, the hoops must be closer to each other near the bottom, or of heavier iron. The lower may be placed 6" from the bottom; the next, 2 feet higher; the third, 2½ feet above this; the others at 2½, 3 and 3½ foot intervals, according to the height of the silo.

If the rods are secured by a few staples they will be prevented from falling when the staves dry out and a collapse of the structure may be avoided. However, the nuts upon the rods should be tightened when the silo is empty and staves become dry, and loosened again when the silo is refilled. Unless loosened the expansion of the staves from the absorption of moisture may result in broken hoops. If sufficient hoops are used to insure the proper strength, and if proper attention is given to keep them properly tightened or loosened, the longevity of a good stave silo is insured; otherwise, it may be very short-lived. The Wisconsin Experiment Station advises also the use of a wooden hoop at the top and at the bottom, to which the staves are nailed. This distributes the shrinkage when empty, preventing any large cracks. They also recommend some wooden hoops laid on diagonally as braces to prevent racking out of plumb.

The doors for the stave silos may be cut from the staves. When erecting the silo, one stave, which comes upon the side where the doors are desired, may be sawed partly across at points where the bottom and top of each door is to come.* After the silo is completed the doors can then be sawed out without making auger holes. In starting and cutting out the doors, the cut should be made upon a bevel, so that the inner side of the door will be larger than the outer side; then pressure of the silage holds the door in place and if, when the door is put in at time of filling, the joint is covered with tarred paper or thick plastic clay, a practically airtight joint is secured.

The King Silo. The King silo is the typical "frame" silo. Pices 2"x4"x2' are imbedded in the foundation wall for sills. Studs 2"x4", or 2"x6" in very large silos, are erected at the joints of the sill and secured to a 2"x4" post placed in the center of the silo. When all are in place, ½" sheeting ripped from 1"x4" or 1"x6" pieces is nailed to the studs. Over this is placed building or tarred paper, then another layer of ½" sheeting, then another layer of paper and a layer of sheeting, making three layers of wood and two of paper in the lining. Upon the outside one layer of sheeting covered by weather boarding may be used. A cheaper covering is to construct bands around the silo at proper distances of three layers of ½"x4" pieces (breaking joints properly). To these hoops or bands ordinary boxing, with or without battens, may be nailed. Galvanized iron could be used in the same manner.

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* Plate I-C — a, b, c.

The Plastered or Gurler Silo is a modification of the above, in which the lining is composed of one layer of sheeting covered with wood or metal lath and a coat of cement plaster. This silo has been found to be very satisfactory in service and quite reasonable in cost of construction. The doors for frame silos, and often for stave and masonry silos, are made of two thicknesses of matched flooring with tarred paper between. Upon one face the boards are placed horizontally and upon the other vertically. Either of these frame silos may be used without the outer wall, but, with the latter, especially, a few wooden hoops should be put on. With the studs exposed, however, the structure is rather unsightly.

Proper circulation of air between outer and inner walls for protection against rotting is secured by boring holes through the outer wall at the bottom and inner wall at the top, covering these with wire netting to exclude rats.

The Octagonal Silo. Another modification of the frame silo is the octagonal silo, with 2"x8" planks used horizontally in place of hoops and serving as nail ties in place of the studs. At the lower part "rims" of these 2"x8" pieces, nailed together at the ends, are placed at intervals of one foot. Above this they spread to 1½ feet apart and at the top to 2 feet. The inner lining may be made of a good grade of boxing—two layers, with tarred paper between and with joints properly broken so that cracks can not occur. The original silos were square silos, in which there was great loss of silage in corners and along the walls which "sprung" with the pressure. The octagonal reduced the loss somewhat. It marks a transition stage between square and round silos. Only round types are now built.

MASONRY SILOS.

There are several types of silos in which little or no wood is used in their construction, such as the stone silo, the brick silo, the clay tile silo, the cement block silo and the concrete silo.

The choice of material depends upon availability or relative cost of the same, since, if properly built, just as good a silo may be built with one of these materials as with any of the others.

Where stone is plentiful, it may be used in making a stone silo, or the stone may be crushed and used in making a concrete silo. In many of the states clay is more plentiful than crushed rock, and brick and tile silos are the more economical. In a section where no clay or rock is available, but where sand is plentiful, it would seem that the cement block silo could be more cheaply constructed.

This type of silo may be constructed with either a solid or a hollow wall. When using clay building tile or certain types of cement blocks no extra labor or care is necessary to construct a wall which is more or less hollow, but with concrete, special forms are necessary; and with brick, care must be taken to keep the outer and inner walls well bonded together.

Since there is no possibility of silage being frozen in Hawaii, it would seem that the only advantage of a hollow wall might be in a reduced cost of construction, less material and labor being required.

The Monolithic or Concrete Silo. This form of silo is probably the one best suited to Hawaiian conditions and materials. Sand and rock are easily obtained and men skilled in the making of forms and in handling concrete are almost always available. When white sand is not available, the black or volcanic sand may be used. However, before being used, it requires several washings for the removal of the clay which is intermingled with it. Upon the Parker Ranch one silo was made using black sand, but in later ones finely crushed rock was used, to avoid the work necessary to wash the black sand. To obtain this material, besides the regular rock crusher and screens, a separate small crusher operated by a separate engine is used.

The mixing of the concrete may be done in a power machine, a hand machine, or by hand upon a mixing board. The proportions used are generally 1 part of cement, 2 parts of sand and 4 parts of gravel; but this may vary under varying conditions, such as different thickness of walls, the amount of reinforcement, or the cleanness of the sand and gravel; 1—1½—3 and 1—2½—5 formulae being sometimes used.

The Amount of Materials for Concrete Construction. Bulletin No. 214 of the Wisconsin Experiment Station gives the materials necessary for a silo 14x36 feet with 6″ wall as follows:

Mixture 1—2½—5.

SILO PARTS	Cement bbls.	Sand cu. yds.	Gravel cu. yds.	Concrcte cu. yds.
Foundation footings	1.87	.77	1.54	1.75
Floor	2.67	1.1	2.2	2.5
Foundation wall 4 ft. high	7.46	3.07	6.14	6.98
Wall 32 ft. high	28.99	11.92	23.74	27.1
Roof	3.21	1.32	2.64	3.0
Total	44.2	18.18	26.22	51.33

Note:—If the sand and gravel are clean and care is exercised in mixing, a 1—2½—5 mixture is sufficient. If not, use a 1—2—4 mixture, in which case add 7 bbls. cement, 1 cu. yd. sand, and 1.1 cu. yds. gravel.

For estimating the amount of material in silos with other dimensions the following tables and directions are given in the same bulletin:

Materials for One Cubic Yard Concrete.

	Mixture 1-2-4	Mixture 1-2½-5
Bbls. cement per cu. yd. of concrete...........	1.3	1.07
Cu. yds. sand per cu. yd. of concrete...........	.42	.44
Cu. yds. stone per cu. yd. of concrete...........	.84	.88

*Materials per Foot in Height of Silos.**

Mixture to be one part cement, 2½ parts sand, 5 parts gravel, and wall to be 6 inches thick.

Diameter	cement	Sand	Gravel
Feet	Bbls.	Cu. yds.	Cu. yds.
10	.65	.269	.538
12	.778	.32	.642
14	.903	.372	.74
16	1.03	.422	.844
18	1.16	.475	.95
20	1.27	.525	1.05
22	1.4	.576	1.15

Forms for Concrete Silos. At least the outside form must be of small dimension (height), otherwise an unnecessarily high lift of material would have to be made. A cheaper form can be made when the inside form is built in a similar manner—but the inside wall may not be vertical unless great care is observed in adjusting the inside forms.

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* **These figures do not include ROOF, FLOOR or FOUNDATION.**

Where many silos are to be built, the labor of moving the inside form may be avoided, and the cost thereof offset by the use of the more expensive continuous inside form—which also insures a vertical wall.

The materials and methods of construction for forms for a 6″ wall of a 14′ silo are thus given in the bulletin above quoted:

Main Frame—16 pieces 2″x12″ 12′ long No. 1 pine.

Outside Form—4 pieces 2″x8″ 10′ long No. 1 pine; 6 pieces 2″x6″ 10′ long No. 1 pine.

Inside Form—4 pieces 2″x6″ 10′ long No. 1 pine; 6 pieces 2″x4″ 10′ long No. 1 pine.

Connections—4 pieces 2″x8″ 10′ long No. 1 pine.

Roof Form—8 pieces 2″x4″ 18′ long No. 1 pine; 4 pieces 2″x8″ 14′ long No. 1 pine; 2 pieces 1″x6″ 14′ long No. 1 pine; 1 piece 2″x4″ 11′ long No. 1 pine.

Door—1 piece 2″x6″ 10′ long No. 1 pine; 1 piece 2″x2″ 10′ long No. 1 pine.

Nails—15 pounds 20d wire spikes; 5 pounds 6d wire nails.

Bolts—Outside Form—16 ½″x4½″ carriage bolts.

Bolts—Inside Form—96 ½″x4″ carriage bolts.

Galvanized Sheet Iron No. 18—8 pieces 6′ long by 2′ 6″ wide; 8 pieces 6′ 6″ long by 2′ 6″ wide.

The 16 pieces 2x12 inches 12 feet long should be cut so that two pieces will be obtained, one 6 feet 6 inches long and the other 5 feet 4 inches long. These pieces are for the outside and inside forms. To lay off the circle for the form, select a level place in the shop or barn, take a narrow strip of wood 1½ or 2 inches wide and 8 feet long, bore a hole in one end of the size of a lead pencil, measure from the center of this 7 feet 6 inches and drive a nail through. This will make the outside circle. Since only one-eighth of the circle is required, it will not be necessary to make a complete circle at this time. The inner circle is made in the same way by shortening the distance 6 inches between the nail and the pencil.*

Two patterns are necessary—B, Plate 1, for the inside form, and A, Plate 1, for the outside form. For the outside form, take one of the pieces 6 feet 6 inches long. Using a steel square, locate the center on one side. From this center lay off 2 feet 10½ inches each way. Place this edge of the piece toward the center of the circle, and under the 8 foot arm which was prepared for drawing the circle. With the pencil at one of the points just made, draw a curved line to the other point.

** Plate I-G.

This will be one-eighth of the outside circle as shown at D in Plate 3. Cut this piece as shown at A in Plate 1, and the pattern for the outside is complete. Cut 16 of these pieces and they are ready for framing into sections.

Take one of the 16 pieces 5 feet 4 inches long, as shown in B, Plate 1. The center is then determined as before. Measure off 2 feet 5 inches each way from the center. Lay this piece under the 8 foot arm, and with the pencil 6 inches nearer the center of the circle, draw a curved line from one end of the piece to the other. This will be one-eighth of the inside sircle as shown at C, Plate 3.

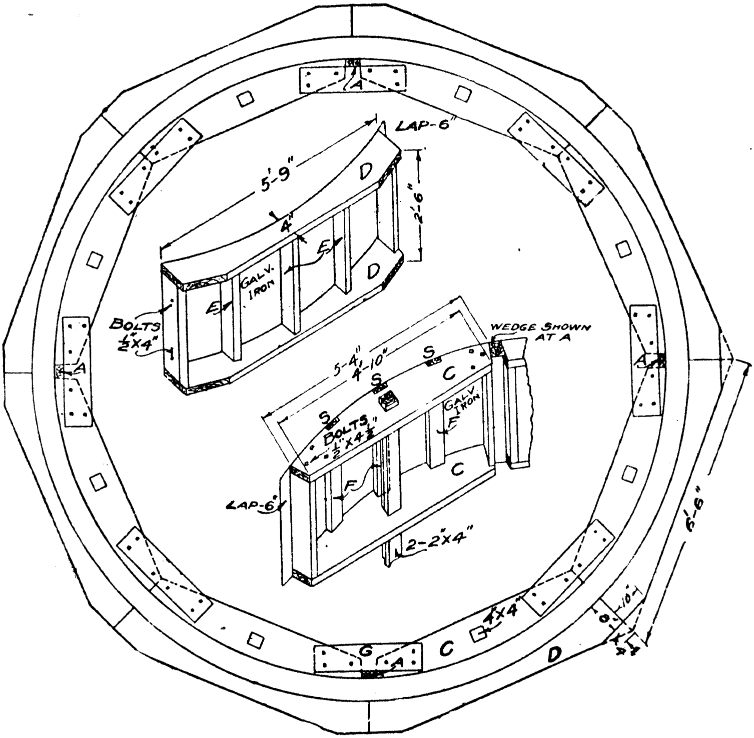

PLATE 3—

Sections C and D shown in circular position as they would appear from above. Note the wedges at A. These should always be released and the connections at these points unbolted when raising the forms preparatory to filling.

To complete the construction of the outside form, take four pieces of 2x8 inches 10 feet long, and six pieces 2x6 inches 10 feet long and cut them into studding 2 feet 2 inches long, as shown at E in Plate 3. Then spike the D's and E's together, using 2x8 pieces at the ends, and the frame is ready to be faced with No. 18 galvanized iron. Care should be taken to square the frame before nailing the iron on. Use six penny wire nails for this purpose.

The studdings as shown at F, F, F, Plate 3, for the inside form are the same except that they are 2 feet 6 inches long. The framing of this form is the same as in the outside form, except that three center studdings are mortised into the inside frame as shown at S, S, S, in Plate 3.

Cut 4x4 openings as shown in C, Plate 3. These openings are for the two pieces, 2x4, used to support the inside frame. By breaking joints these supports may be raised to the height of the silo. They must always be perfectly plumb.

The sections should be set and bolted together in a circle, placing the inside form first. To do this, describe a circle with a pencil and arm as before explained. From the four pieces 2x8 inches 10 feet long make 16 connections 2 feet 6 inches long, and bolt one at top and bottom of each section as shown at G, Plate 3. A second circle 6 inches outside of the other should then be drawn and the sections of the outside form set in place as shown at D in Plate 3. To keep the outside form just 6 inches from the inside form, make up several pieces 6 inches long for spacers. These should be placed 4 or 5 feet apart.

For 16, 18, or 20 foot silos the forms are constructed in the same manner, but the dimensions of the various pieces will of course be different. Lay off the circle upon the ground; divide it into eighths, and cut the inner and outer forms to meet at the dividing lines.

*Reinforcement of Concrete Silos.** The material used for strengthening concrete silos is of various kinds. In the Oklahoma Farm Journal for February 15, 1913, a writer mentions using, with 3 foot forms, a 34" woven wire fencing. Each fill was 32 inches, so that the fencing was lapped two inches and no weak point occurred between fillings.

Upon many of the farms in the West, there is usually a surplus of worn out farm machinery, some portions of which are always available for reinforcing. Iron rods ⅜"-⅝" in diameter are common commercial forms for reinforcing. In the absence of other materials or as substitutes for them ordinary smooth No. 9 wire may be used in the form of cables. Barbed wire could be used and would perhaps be better, but it is difficult to handle. Wire cables are easily made in any length desired and afterwards they can be cut into shorter pieces. Take a heavy wagon and raise one wheel upon a wagon-jack or block and brace thoroughly so as to prevent any movement forward, backward or to the side. At the desired distance from the wagon set a heavy post and attach to it the ends of several wires. The wires are then attached to every fourth or fifth spoke upon the movable wheel, near the hub. Upon turning the wheel the wires are soon twisted into a cable. Rods and cables should be placed near to the outer edge rather than to the inner edge of the wall.

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* **For reinforcement about doorways see Plate I-F.**

In silos over 25 feet high, vertical reinforcement should be employed as well as horizontal. Three-eighths inch rods at intervals of 15 to 30 inches are recommended, but not always used. If cut into short lengths, rods or cables can be more easily used as vertical reinforcement.

Concrete, because of the strength of the cement, requires less reinforcement than stave, brick, tile or block silos.

The following table, from Wisconsin Bulletin No. 214, gives the approximate amount of reinforcement to use.

Amount of Reinforcement Needed for Silos.

Size and Spacing of Horizontal Reinforcement Around Sides.

Distance in Feet Measured From Top of Silo	For Silos 14 ft. to 18 ft. in Diameter, Using No. 9 Wire		For Silos 14 ft. to 18 ft. in Diameter, Using ⅜ Inch Mild Steel Rods	
	No. of Wires in Cables	Distance Apart of Cables	No. of Rods	Distance Apart of Rods
		Inches.		Inches.
0- 5	2	12	1	18
5-10	2	10	1	18
10-15	2	8	1	14
15-20	4	8	1	12
20-25	4	6	1	10
25-30	4	6	1	8
30-35	5	6	1	6
35-40	5	4	1	4

If there is a scarcity of reinforcing material, the lack may be made up by using a greater proportion of cement in the mixture, or by making a thicker wall.

Upon the Parker Ranch on Hawaii are now being constructed several concrete silos. The forms in use may be described as follows: The outer form is similar to the one de-

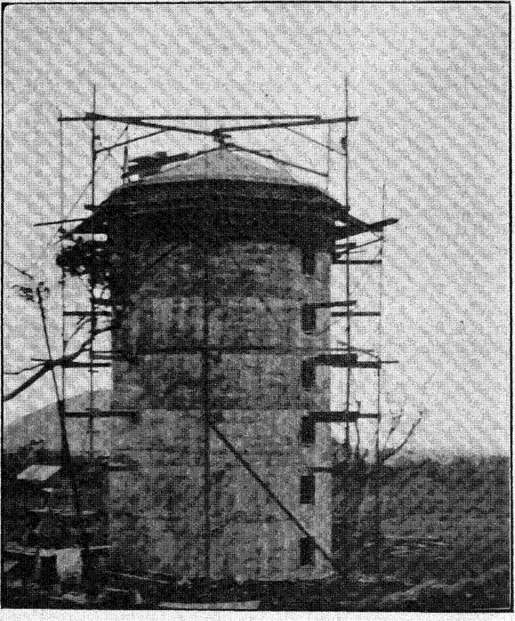

PLATE 4—
Concrete Silo on Parker Ranch. Dimensions 20'x40'.
Concrete mixing machine in view, at left.
Scaffolding in place. Outer form still on at the top.
Roof nearly completed.

scribed and illustrated above with the exceptions that vertical staves of 1"x4" shiplap are used in place of the galvanized iron, and the form is 5' high in place of 3'. Only two 2"x4" studs are used upon each section with the shiplap where more were necessary with galvanized iron.

All the joints are made secure by bolts as shown, but one.

At this one two large bolts 30″ long are used. These bolts are placed horizontally, one near the top of the form, the other near the bottom. The form may be loosened when desired by unscrewing the nuts of these bolts. Then the form is raised by four sets of pulley blocks hung from the scaffolding and the bolts are tightened, after which everything is ready for another fill.

The inside form is made of shiplap 1″x4″ by 20′ with braces, made as described, occurring at bottom, at 10 feet high, two at 20 feet where the upper section meets the lower, another at 30 feet, at 35 feet and at 40 feet.

The dimensions of these silos are 20x40 feet with an 8 inch wall the entire height. The capacity of each is nearly 300 tons.

The scaffolding consists of 4x4 inch post in the center of the silo, several 4x4 inch and 3x4 inch posts upon the outside. These outer posts are connected to the inner one at intervals by 1¼x6 inch pieces and across these the platforms are constructed, the entire scaffolding being well and securely braced so as to avoid accidents. The inner form is well braced also from the inner post.

THE IOWA OR HOLLOW CLAY TILE SILO.

This silo is simple in construction, durable, efficient, and reasonably cheap where the tile can be obtained. It is built of regular clay, hollow building blocks 4″x8″x12″ or of dimensions approximating these. The tile are laid in cement mortar which contains just enough lime to make the mortar stick well, (1 part cement, 1-3 part lime, 2 to 3 parts sand). No. 3 wire is laid in for reinforcement, the amount of wire used being adjusted to meet the demands of the lateral pressure. The inside of the tile may be plastered—or simply washed with a cement wash.

THE CONCRETE BLOCK SILO.

When once the concrete blocks are made, the construction of this form of silo is the same as that for the one preceding. In the manufacture of the blocks, a form consisting of a bottom board, and hinged or bolted side pieces are used.* From one to five of the side pieces or frames are necessary while thirty to fifty of the bottom pieces are required. In making cement blocks as in making posts but little water is used because with little water, the material soon hardens and the side frames may be removed and used in making more blocks.

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* See Plate I, H and K.

In order not to disturb the cement until set, the block must be left upon the bottom board for some time, at least 3 to 4 days, and hence more of these bottom than of side pieces are necessary.

The properly "cure" blocks made in this manner, a period of at least three weeks is necessary, during which the blocks must be kept from drying too rapidly. They are sprinkled well and frequently, and covered with old hay, straw, sacks or with tarpaulins to protect them from the sun. By having several of the side forms, immediate removal of the form is unnecessary, more water can be used and a stronger block obtained.

A convenient size of block is 8"x8"x24". To make these as light as possible and to save material the Wisconsin Station advises the use of two cores 2" thick, 8" long and 6" wide—tapered toward one end so as to be easily removed.

Forms for making such blocks are inexpensive and any one can make them. Concrete block machines are more expensive but permit more rapid work in making.

For reinforcement 3-8" iron rods are used between each layer up to 15 feet after which a less number may be used. Michigan Experiment Station Bulletin No. 255 fully describes several different block silos. One of these may be briefly described as follows:

Silo—16½ feet diameter. 28 ft. high above concrete foundation.
Blocks—9"x36" and 10", 8", or 6" thick.
12 tiers of hollow block 10" thick.
14 tiers of hollow block 8" thick.
12 tiers of solid block 6" thick at top.
Cores for making hollow blocks—2"x10"x9" (tapering).
Concrete—1 part of cement, 5 parts gravelly sand.
Mortar—1 part of cement, 2 parts sand.
Plaster (½")—1 part of cement, 2 parts sand.
Wash—Cement and water.
Reinforcement—No. 8 wire.
Time to build—3 weeks[1].
No. of blocks—700 (1 bbl. of cement to 16 eight inch blocks).

Another type of silo is described as follows:
Blocks—solid—8"x24" by 3" thick.
Doorways—continuous—no door frame.
Reinforcing—2" band iron hoops as for stave silos with 1½"

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[1] No data given as to time required to make the blocks. In another description it is stated that 3 men could make daily 100 blocks 8"x10"x32".

x4" pieces across doors, under the hoops, to hold wall, and to which supports for a chute are nailed. Hoops 33" apart. Concrete, mortar, and plaster—as usually made and a cement wash was put on over the plaster.

The unique features are the thinness of the walls, and the hoop reinforcing, no wires being used in the walls. Also much less material is required and cost is reduced. The contract price of this silo—with foundation, and frame, rubberoid roof was $176.00 and it had been in use five years at time the bulletin was published.

Steel silos are now upon the market but no reports as to their efficiency are as yet available.

Care of Silos.

For concrete silos, care consists of washing the inner surface every 3 or 4 years with a cement wash. Wood silos may be painted on the outside at intervals as necessary.

Interior walls may be painted only with hot gas tar or creosote.

Plastered silos may be given the cement wash.

Stave silos should be watched. The staves should be tightened or loosened as before stated.

When well built—silos require little subsequent attention.

CROPS FOR THE SILO.

The corn plant is preeminently the one for silage. It furnishes nutritious feed, good yields per acre, ease and cheapness in handling, and a wide adaptability to climate and soils. Other crops can be used alone or in mixtures, but none can ever replace corn entirely. Alfalfa, clover, cowpeas, soybeans, sorghum, Japanese cane, and other crops have been used. In New York state corn and soybeans have been quite a popular mixture; sorghum and cowpeas make a better soiling food throughout the South and could be used as a mixture for silos. Sorghum and velvet beans also make a good silage according to the Florida Station. Velvet beans alone do not make good silage and the silage from soybeans is very foul smelling.

In Hawaii we have several crops which could be tried out for silage. Corn, alone, or with soybeans, cowpeas or alfalfa will probably be found to be superior to other crops. Sorghum, alone or in mixtures will prove to be of value. Cane tops, where they can be obtained without too great an expense in hauling, should prove successful as silage. Honohono, Para grass, alfalfa, soybeans, cowpeas, velvet beans, jack beans, teosinte, clovers, and other crops will no doubt keep well and succeed as silage crops.

It is well of course to try and grow some legume to mix with corn, sorghum or other grasses in the silo. The yields of soybeans are not satisfactory at all times; aphids interfere with growth of cowpeas; cutworms kill peas and beans at various times; alfalfa is not suited to all our varying conditions; jack beans and velvet beans are rather slow in growth. Experience alone will enable one to determine which legume is best suited to his particular needs. Ti leaves and prickly pear are feeds which could be tried out. However, the latter feed is succulent and green at all times and might not be improved by ensiling, and the labor bill would be unnecessarily increased.

Marsh rice, cut in the green stage, could be tried along the coasts and perhaps in rainy districts the upland rice would give good yields and feed. A rainfall of at least 10 inches per month is necessary for the best growth of this rice. Egyptian clover has done very well at the Experiment Station and where rainfall is plentiful during winter months, might be grown for mixed silage. Red clover might succeed at higher altitudes. Cowpeas will likely prove to be the better legume under all conditions.

Professor Krauss at Kamehameha succeeded well with corn, sorghum and cowpeas and with cowpeas alone. Vines like cowpeas or velvet beans are somewhat difficult to run through the cutter alone. They should be mixed with twice or three times a like amount of sorghum or corn.

Japanese Cane. Florida Station Bulletin No. 105 gives a good recommendation for Japanese cane as a forage and silage crop. It is given special mention here as worthy of trial where there is a reasonable amount of rainfall at lower or medium elevations. It should be planted in rows about 6 feet apart and it will make several ratoon crops like the regular sugar cane. It will be eaten fresh or as silage by all kinds of domestic animals. It will furnish a much larger quantity of forage, richer in carbohydrates, but poorer in portion, than will corn or sorghum.

YIELDS.

Corn. Carrier (Farmer's Bulletin No. 292) found that the average yield over a considerable area in Michigan and Wisconsin was 9.1 tons green feed per acre. In Nebraska 18 acres of corn (estimated to make 60 bushels per acre)) were required to fill two 110 ton silos, which equals about 12 tons. The Pennsylvania Station also estimates a 60 bushel corn crop at

12 tons and a 40 bushel crop at 8 tons per acre. Maximum yields of corn are 15-18 tons per acre, the yield being obtained by dividing the number of bushels the land will produce by five. A test row from a plot in Nuuanu Valley yielded at rate of 9.8 tons in March, 1913.

Sorghum. Sorghum in Florida yielded better than corn and varied from 8 to 16 tons per acre. Rattoon crops, if moisture is available, would give sorghum a preference over corn. In Hawaii yields of from 5 to 24 tons have been obtained. One variety has exceeded this. All sorghums grow slowly during the cooler months.

Japanese Cane. Japanese cane in Florida gave 16 to 27 tons in 1909 and 10 to 16 tons in 1910. At Mountain View (Olaa Plantation) Hawaii, yields of over 50 tons per acre were obtained for two years, after which much less was obtained.

Teosinte yielded less than sorghum in Florida but in Louisiana 50 tons per acre were obtained. At the Hawaii Experiment Station it yielded about the same as sorghum and made no rattoon.

Jack Beans. Yields at the rate of 11 to 12 tons per acre have been obtained at the Hawaii Experiment Station. P. M. Pond secured one crop of 20 tons per acre, but could not duplicate it.

Velvet beans upon a small plot yielded at the rate of 19.8 tons per acre.

Cowpeas yield 5 to 10 tons per acre.

Alfalfa will make from 2 to 8 tons per acre, per cutting.

Of soybeans, clovers, etc., no yield under Hawaiian conditions are available. It will likely be less than for the cowpeas, jack beans or velvet beans. Yields of course are very variable and uncertain. The nature of the soil, its water holding capacity, prevalence of winds, amount of sunshine, humidity of the air and the adaptability of the crop to the given conditions are some of the factors which determine yield.

Cost and Value of Silage. The cost of silage includes the cost of growing the crop, the rent of the land, the cost of filling the silo and some proportion of the cost of the silo, the feed cutter, etc., the estimate of the latter being based upon their longevity. By calculating the cost and dividing by the number of tons in the silo, the cost per ton will be obtained. The value of silage is really the value of other feeds which one would have to buy to obtain the same result were the silage not on hand. Most of the experiment stations in the States in figuring the result of feeding tests estimate silage as worth $3.00 to

$4.00 a ton. One experiment station values silage at $3.50 per ton or what would be seventy cents per bushel for corn. As the average estimates are that a "5 bushel" corn will make 1 ton of silage, the approximate value of silage per ton is obtained by multiplying the price per bushel of corn by five.

FILLING THE SILO.

The crop should be left in the field until nearly mature—until the leaves show by a yellow color that maturity is near. With corn, the best stage is when kernels are in the "dough." Sorghum may be left until more fully mature. Better silage is made from maturing crops and better yields are obtained.

Corn and sorghum may be cut with a binder (or harvester as some call it) if they have been grown in rows. However, if blown down badly, hand labor must be used. The cost of cutting by machinery is not much less than by hand labor, but the bundles are much more easily and quickly loaded on wagons and unloaded at the cutter making a saving of time. One third more corn can be handled in a given time in bundles. It is well to haul a few loads and stack by the cutter in such place as will not interfere with the approach of the wagons. Then if there is any delay in getting fodder in from the field, corn may be secured from this stack to keep the cutter running. It is best, although not necessary, to fill the silo as expeditiously as possible, once the work has started. After the silage is well settled or after 4 or 5 days the silo may be refilled. Several refillings are necessary. The settling may be facilitated by thoroughly wetting the upper foot of silage to increase its weight. When finishing filling (the final filling) weeds, grass, cornstalks without the grain and any other materials may be used, wet down as described; since the top is exposed to the air and will spoil, poor material answers as well as good. When opening the silo to begin feeding some ten or more inches at the top will be found to be spoiled and must be thrown away.

It is possible to ensile partially dried corn fodder by adding water to the cut material upon the elevator, one-half barrel or less to the wagon load of fodder. There is a tendency because of the difference in their weight for the cut pieces of cob, stalk and leaves to segregate. One man should be kept in the silo when filling, whose duty it is to keep these well mixed, and to keep the silage well tramped near the walls. The mass in the center settles well without tramping, but friction along the walls retards settling and hence the need for thorough tramping at the edges.

Fermentation starts immediately and when resuming the work of filling after any interval the machine should be run several minutes before any one enters the silo. Carbon dioxide develops and accumulates in the bottom but will be dissipated by the falling silage. Especially in pit silos should care be observed.

Cutter. Use one of large capacity rather than a small one. There will be less trouble and delay and the cost of filling the silo will be reduced if large capacity machines are used. To elevate the silage the cutter may be equipped with either an elevator or a blower. Blowers are to be preferred especially for high silos, but much more power proportionately is required. Force feed (or self-feed) machines have a greater capacity for same size of knives. There is less danger of injury to the feeder or to the machine with these machines, since in any emergency the feeding device may be instantly disengaged and stopped without stopping the cutting part of the machine. The exact size to which the feed is cut is of but little importance—uncut feed would keep if it could be packed tightly enough to exclude the air.

Wagons. For convenience in hauling in the fodder from the fields either a low wheeled "handy" wagon may be used or ordinary wagons with extended "drop frame," reaches, so that the main rack or platform is low and convenient between fore and hind wheels. To build this frame two pieces of 3"x12" or other heavy material about 16 feet long are fitted together making a narrow "V" wedge. The point of the "V" is hung below the forward axle by a heavy bolt which replaces the "King" bolt. The open end of the wedge is suspended below the rear axle to which it is attached, the "hounds" being attached to this frame which substitutes for a "reach." Over the heavy timbers a floor, a front standard and a rear standard are built to hold and retain the fodder.

The labor required in filling a silo is considerable. Several men are necessary in the field to cut and load the corn, two or more teamsters in hauling, two men to unload and feed the cutter, one man inside the silo and at least another to attend to the engine. If steam power is used, or if water is necessary to dampen dry fodder, a man to haul water is also required.

The cost of filling in Wisconsin and Michigan, according to Carrier, varied directly with the size of loads that were hauled, and with the distance. Accordingly then, a low cost in filling will be obtained by locating the silo near to the cultivated fields and below them so that maximum loads may be hauled.

Carrier found the cost per ton upon 31 farms to be $0.64 and the cost per acre to be $5.98. In Nebraska the cost was found to be from $1.75 to $1.95, while in New Jersey it was $1.30.

FEEDING SILAGE.

As stated above, when feed is desired, remove the spoiled portion at top and then a few inches each day so that no silage will be exposed sufficiently long to spoil. Professor Krauss found in his experience with the first silo in Hawaii at the Kamehameha Schools that about six inches must be removed daily to avoid loss by molding. Feed small amounts until animals become accumstomed to it. As the silage is laxative in its effect, several pounds of dry feed should be fed with it. Frozen silage causes scouring in cattle and moldy silage is thought to have killed nine horses out of eleven in one instance —the horses showing symptoms of cerebro-spinal meningitis.

Tainted milk will be noticed from cows fed on silage unless they are fed after milking, and unless the stables are kept clean and well aired, and the milk cared for and removed before feeding the silage. The amount of silage to feed depends upon the species of animal and the purpose for which they are fed. Cattle fed for maintenance will consume from 20 pounds to 70 pounds daily depending upon the amount of other feed fed, and the weight of the animals. Cows in milk—receiving "full feed" will consume 35—45 pounds daily.

Fattening steers may be fed:

First periods without grain	50-70 pounds.
First periods with grain	25-45 pounds.
Last period with grain	15-35 pounds.

Horses and mules received 21-30 pounds with grain at North Carolina Station (Bul. 189) and worked full time and gained slightly during the experiment.

Fattening lambs—5 to 8 pounds with grain. Lambs consume about as much hay as silage if offered both. Cattle, however, consume much large quantities of silage.

Conclusion. That silos are a success and of great value to stockmen has been well demonstrated elsewhere. That they are of value under Hawaiian conditions has been demonstrated at Kamehameha School and upon the Parker Ranch, and in an experiment with an old cistern in Kula. By the use of the silo it is certain that a supply of feed may be held over from times of good growing weather to times of drouth. This means a step in advance over the present system in which at times great losses occur.

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Addresses of Manufacturers:

Of silage cutters.

Silver Mfg. Co., Salem, Ohio.
Smalley Mfg. Co., Manitowoc, Wis.

Of steel silos.

The Boardman Co., 501 Culbertson Bldg., Oklahoma City, Oklahoma.

Of stave silos.

Indiana Silo Co., 328 Silo Bldg., Kansas City, Mo.

Western Silo Co., 200 11th St., Des Moines, Iowa.

Des Moines Silo and Mfg. Co., 505 New York Ave., Des Moines, Iowa.

Puffer Hubbard Mfg. Co.

Wood Brothers Silo and Mfg. Co., Spokane, Wash.

Southwest Silo Co., 113 California Ave., Oklahoma City, Oklahoma.

Pacific Tank and Silo Co., Chehalis, Wash.

Of tile silos.

National Fire Proofing Co., Huntington, Ind.

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Of stave silos.

Indiana Silo C

Western Silo C

Des Moines S
Moines, Iowa.

Puffer Hubba

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Issued, April 1st, 19[illegible]

HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 41.

Tin Cans vs. Pots for Seedling Plants.

By

E. V. WILCOX

It has been long observed in the work of propagation at this Station that young seedling plants, such as papaia, mango, avocado, Christmas tree, etc., grow more rapidly and with greater vigor in tin cans than in ordinary florist's pots. A set of experiments was carried out to determine the cause of the difference in growth. It was assumed, as a working hypothesis, that two factors were involved—a difference in evaporation and a possible stimulation due to the tin and solder of the cans.

For the first test two tin cans and two ordinary flower pots were selected. The cans were 3¾ inches in diameter and the pots 5 inches at the top and 3 inches at the bottom. All four containers received the same amount of potting soil by measure, approximately 760 grams. The potting soil was made by mixing 3 parts of ordinary clay soil, 3 parts of rotted manure and 2 parts of coral sand. It had been sterilized by heat, and in an air-dry state contained about 10 per cent of moisture. To each container 150 C. C. of water was added, bringing the moisture content up to 30 per cent. Holes were punched in the bottom of the tins and the pots had the usual drainage hole. The cans and pots were weighed once or twice daily, and were brought back to the original weight by the addition of water, every other day at first and later every day.

During a period of 17 days the total loss of water by evaporation from the first can was 200 gm.; from the second can 220 gm.; from the first pot 491 gm.; from the second pot 489 gm. Averaging the loss from the cans and pots, the evaporation from pots was exactly 2½ times greater than that from tins. The soil was not shaken or in any way disturbed during the experiment. For the first few days the loss of water from the pots was three times that from the tin cans. At the end of the experiment it was only twice as great. The difference was thus gradually reduced as the soil became packed, reaching in about 10 days what seemed to be a permanent ratio of 1 to 2. The loss of water shown at each weighing was almost precisely the same for the 2 cans, and the same was true for the pots.

In a well ventilated laboratory room and in a ventilated glass-house the ratio of evaporation from tin cans and pots remained constant, but when exposed directly to the sun in the free air the tins showed a relatively greater increase of evaporation than the pots. This was due to the rapid penetration of heat through the tin. Evaporation was of course greatly affected by the humidity of the air. On a rainy day when the air was saturated with moisture the evaporation was only one tenth that of the following clear, dry night.

It was soon found that in order to secure results which were comparable from day to day it was necessary to bring the soil back to the original moisture content each day. Otherwise, on the second day, the soil on the surface of the pots, as well as that in contact with the sides becomes much drier than that in the tins, and the evaporation is thereby somewhat checked.

The porosity of flower pots varies greatly. Some of them allow the water to pass through so readily that an efflorescence of soluble salts is formed on the outer side of the pot. In order to compare the rate of evaporation from the exposed upper surface of soil in tins and pots a pot was heavily coated by dipping in melted paraffine, received the same moisture content as the others and was added to the series. No evaporation could take place through the side of this pot. The ratio of the surface of the soil in the tins and pots was as 1:1.5. The evaporation from the paraffined pot was 1.52 times as much as from the

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tins, which corresponds very closely with the difference in exposed surface. It was to be expected that the difference in evaporation would be greater than the difference in exposed surface, for the reasons that the tins and pots contained the same amount of soil and that, therefore, the greater exposed surface in the pots entailed a relatively still greater proportion of the soil near the surface. In other words the soil in a pot is more exposed to evaporation than even the greater surface area would indicate.

In order to determine the relative amount of evaporation through the side of the pot and from the upper surface of the soil, another pot was added to the series. This pot was covered so as to prevent any evaporation from the upper surface of the soil. During the period of the experiment the sum of the loss from the upper surface of the paraffined pot and through the sides of the covered pot almost exactly equaled the average loss from the untreated pots. The average loss for a period of 3 days from the two untreated pots was 40 gms., and the sum of the loss from the paraffined and covered pots was 39 gms., the covered pot losing 18 gms. and the paraffined pot 21 gms. From these figures it is apparent that with the ordinary flower pot 52.3 per cent of the evaporation takes place from the top and 47.7 per cent through the side. The area of surface (side and bottom) of each pot in contact with the soil was 58.6 square inches, and the area of the top of the pot 17.8 square inches. From these figures and those of total evaporation it was easily calculated that the evaporation from a given area is 3.5 times as fast through a free surface of soil as through the side of the pot. The greater area of the side makes the evaporation from the side almost equal to that from the top.

Young uniform seedlings of a species of Schinus (Christmas tree or Hawaiian holly) were planted in 10 cans of the same size as those used in the above-mentioned experiments with the same quantity of potting soil, and also in 10 pots. Five of the cans and five of the pots were coated with paraffine to eliminate any effect which the containers themselves might have on plant growth. The plants in all the tins and in the paraffined pots received 60 C. C. of water every two days, and the unparaffined pots 120 CC. Of the latter 5 pots 2 were very porous while the other 3 were equally porous with those used in the simple evaporation test. The plants were as near uniform as possible at the start. At 2 months of age the plants in the 2 very porous pots were 3½ inches high, those in the 3 medium-porous pots 4½ inches, those in paraffined pots 5¼ inches, those in paraffined tins 6¼ inches, those in untreated tins 7½ inches. The height and vigor of the plants showed a regular series of gradations, increasing in size as the evaporation from the container decreased (See fig. 1).

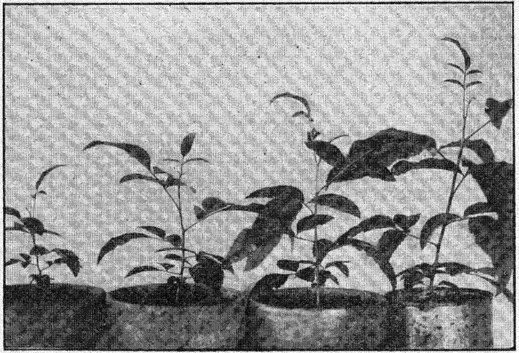

Fig. 1. Growth of young Schinus plants in different containers. From left to right: Very porous pot, medium porous pot, paraffined pot, tin can.

At the age of 2 months 2 plants in untreated pots and 2 in untreated tins were selected for daily weighings. The soil in all 4 containers was brought to a moisture content of 30 per cent, which was maintained by bringing it back daily to the original weight by the addition of water. For comparison the 2 pots and 2 tins from the previous experiment and without plants were added to the series. The loss of water by transpiration was calculated by subtracting the loss in the tins and pots without plants from the loss from the pots and tins with plants. For a period of ten days the total evaporation from the two tins without plants was 90 and 102 gms. respectively, and the loss from the two tins with plants 301 and 295 gms. showing a transpiration of 211 and 193 gms. respectively. For the same period the evaporation from the 2 pots without plants was 186 and 201 gms. and the total loss from the pots with plants was 304 and 310 gms. giving a transpiration of 118 and 109 gms. respectively. At this stage of growth, therefore, the greater loss of water by evaporation from the pots was approximately balanced by the greater transpiration by the larger plants in the tins. A careful measurement of the leaf surface was made, indicating the leaf surface of the plants in tins to be 1.6 times greater than that of the plants in pots, while the transpiration was twice as great. The plants in tins were growing more vigorously and were obviously transpiring more water per unit of leaf surface.

During the period of 10 days just mentioned the 4 plants outstripped the rest of the group from which they were selected. They were of the same size at the start but at the end of the 10 day period the two plants in tins were 3 inches taller than the other 3 plants in tins and the two plants in pots showed a similar increased growth. This shows the importance of maintaining the optimum moisture content as uniformly as possible. The only advantage enjoyed by the four plants which made the greatest growth consisted in the fact that the original optimum moisture content of the soil was restored each day by adding precisely the amount of water lost by evaporation and transpiration during the preceding 24 hours, while the other plants received the same amount of water each day. On humid days this was too much and on dry days it was too little.

The great advantage of using tin cans rather than porous pots seems to rest in the fact that in tins it is easier to maintain a nearly constant moisture content without a rapid drying of the soil about the growing roots. This results in a more rapid and vigorous growth. Since nearly one-half of the evaporation from pots takes place through the side of the pot, the movement of this part of water is necessarily in a horizontal direction. Root growth responds to the direction of the water movements in soil. Therefore, the roots reach the side of the container more quickly and in greater numbers in pots than in tin cans. The difference in this regard is striking in all plants with which we have experimented (See fig 2). For example seedling papaias, grown in pots, show a felted mass of roots on the outer surface of the ball of soil in the pot. After watering the soil rapidly dries by escape of water through the side of the pot, thus leaving the young rootlets too dry. By the shrinkage of the soil away from the side of the pot in drying a space is formed into which the water runs upon the next watering. The roots are thus alternately exposed to the air and submerged in water. In tin cans these conditions do not occur. No water can escape through the tin. The moisture content of the whole ball of soil is uniform and consequently the roots distribute themselves uniformly through the mass.

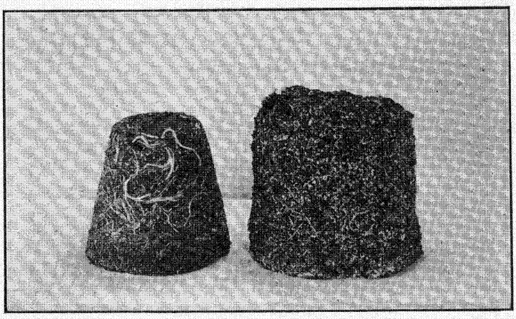

Fig. 2. Habit of root growth of papaia roots; on left in pot, on right in tin can.

When used in growing seedling plants tin cans show quite extensive disintegration within a year. Under the influence of oxygen, the soil solution and plant acids, salts of tin, zinc and iron are formed from the can and solder. The growing tips of rootlets come in contact with the side of the can, and are in position to absorb these mineral salts. Naturally the salts of the tin and zinc in the soil in tin cans must be in extreme dilution. Under these conditions tin and zinc are known to stimulate plant growth to some extent. Micheels[1] found that colloidal tin had a decided stimulating effect on wheat and oats. Nakamura[2] showed that zinc in great dilution was a marked stimulant. Similar results were obtained by Silberberg.[3]

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[1] Rev. Sci. (Paris) 5 ser. 5 (1906) pp. 427-429.

In the experiments at this Station plants grown in untreated tin cans showed a better color and a more rapid growth than those in paraffined cans. In the paraffined cans the roots could not come in contact with the tin. Since all other conditions were the same it is necessary to conclude that the substance of the tin can itself exerted a slightly stimulating effect.

For the practical propagator these experiments indicate certain suggestions of considerable value. It is impossible to maintain the moisture content of the soil in porous pots as uniform as in tin cans, at least without watering them three or four times daily. Even then there are lateral movements of water through the side of the pot, which bring the roots to the outside of the ball of soil where the variation in moisture content is greater. In these experiments 5 inch pots containing 760 gms. of soil lost about 29 gms. of water daily by evaporation, while tin cans holding the same amount of soil lost about 12 gms. daily. The loss by transpiration depends of course on the size of the plant. A seedling Christmas tree 10 inches high transpires about 21 gms. daily, and one 5 inches high about 11 gms. These are average figures. The amount varies according to the humidity. It is obviously important to maintain the moisture content of the soil as nearly as possible at the optimum point. This can be determined approximately by a simple test similar to that on which this bulletin is based. A measuring device for watering may then be used by which approximately the right amount of water can be applied to each plant. In this way much better results will be obtained than by guessing, at the amount of water required.

The advantages of tin cans over porous pots are several. Flower pots are expensive in Hawaii since we have no material for manufacturing them and they must therefore be imported. Tin cans of various sizes cost nothing except the trouble of going to the pineapple canneries for them, where rejected cans may be obtained in almost any quantity. On account of the flaring top of pots they occupy about 1½ times as much space as tin cans holding the same amount of soil. Pots are easily broken in handling, while tins may be roughly handled without injury. The root development of plants is better in tin cans than in pots. The growth of plants in tins is faster than in pots, for the reason that a uniform moisture content is more easily maintained in tins. We find in practice that plants in tin cans will thrive well when watered only every third day, under conditions where plants in pots require watering every day. This brings about an economy in the cost of watering. Finally there is a slight stimulating effect from the disintegrating wall of the tin can.

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[2] Bul. Col. Agric. Tokyo Imp. Univ. 6 (1904) pp. 147-152.
[3] Bul. Torrey Bot. Club 36 (1909) pp. 480-500.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 42.

Corn Culture and Improvement.

By

C. K. McCLELLAND, AGRONOMIST.

Corn is one of the principal forage and grain crops and the chief silage crop grown. It was not until America was discovered that this valuable plant became known and cultivated in other regions, and it is perhaps not to be wondered at that a crop which has such a wide adaptability to soils and climate, should find its largest acreages and best development upon the American continent where it originated. In both North and South America it is one of the main feeds depended upon by dairy men, general farmers, and stock men. In Hawaii it has been grown for years, and here it has a wide range of adaptability, being grown under various conditions of soils, moisture, elevation and seasons. Upon the higher lands as at Kula and Waikii, it is planted in the spring, while at lower elevations it may be grown at any time, but makes its best growth when assured of plenty of moisture or, upon leeward sides, as a winter crop. The following tables gives the percentage composition of corn, in various parts and conditions:

	DRY GRAIN			Fresh Silage	FIELD CURED		Corn & Cob Meal	WATER FREE		
	Dent.	Flint	Sweet		Fodder	Stover		Horny Portion	Floury Portion	Germ.
Water	10.6	11.3	8.8	79.1	42.2	40.1	15.1			
Ash	1.5	1.4	1.9	1.4	2.7	3.4	1.5			9.9
Protein	10.3	10.5	11.6	1.7	4.5	3.8	8.5	10.	7.	19.8
Crude Fiber	2.2	1.7	2.8	6.	14.3	19.7	6.6			
Nit. free Extract	70.4	70.1	66.8	11.1	34.7	31.9	64.8			
Fat	5.	5.	8.1	8.	1.6	1.1	3.5	1.	.8	34.8

Fodder is the name applied to the entire plant, while stover applies to stalk and leaves after removal of the ears and may or may not include the husks.

In structure the grain is made up of the embryo or germ; the endosperm, consisting of white and horny portions; and the outer covering composed of the *aleurone layer* and the outer hull, the latter being in turn composed of several parts as may be seen under the microscope. Upon one side of a kernel or grain of corn may be seen a depression extending from near the bottom or point of the kernel 1-3, 1-2, or even nearly to the top of the kernel. This shows the position and size of the embryo. When selecting for content of oil or protein, kernels with large embryos are taken.

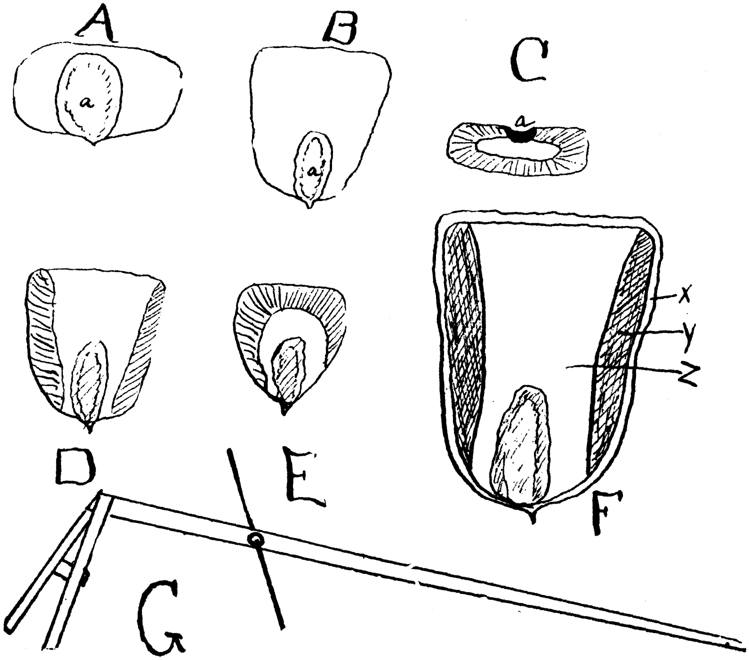

Figure 1:

A—large embryo.
B—small embryo.
C—cross section.
D—split kernel, dent corn.
E—split kernel, flint corn.
F—shows position of aleurone layer (x); and flinty (y) and white starch (z) and embryo.
G—"shocking horse."

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Fig. 1—A, B and C show the position of the embryo in whole kernels and in cross section. If the grain be split through its two largest dimensions the floury and horny portions of the endosperm will be seen as in figure 1—D and E.

Selections to increase starch content must be made of kernels with a large proportion of the white or floury portion. To increase protein content select for large proportion of horny portion and also for large embryo, as implied in the table giving composition of various parts. The aleurone layer is a layer of cells occurring beneath the outer skin and may be seen by removing the latter (by soaking in hot water for about 15 minutes.) In blue, purple or black corn the color is in the aleurone layer. The red color of corn lies in the hull, while yellow and white colors are from the endosperm, or, to less extent, from the aleurone layer. As between the yellow and white varieties, which are the ones more commonly raised, there is evidence that white varieties yield the better but that there is no difference in composition or feeding value.

SPECIES.[1]

Corn is divided into six agricultural types or species, known as pod, pop, flint, dent, soft and sweet, corn—or maize as it is known beyond the boundaries of the United States.

In figure 1-D will be seen dent corn in which the white or floury portion of the endosperm extends to the top. At E, flint corn in which it does not.

In pop corn, nearly all of the endosperm is horny; in soft corn it is all white; in sweet corn, the endosperm is nearly all horny in appearance, the starch having been reduced to sugar; in pod corn each kernel has a separate husk in addition to that covering the ear.

VARIETIES.

The varieties of these species are innumerable. Variations occur in the height and circumference of the stalks, in the length and width of leaves, in the position at which the ear is borne, in the number of ears, in the length and circumference of the shank, in the length and circumference of the cob and ears, in the number of rows of kernels, in their size, shape, color, etc.

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[1] **Bulletin No. 161, Bureau of Plant Industry, U. S. Department of Agriculture describes another type of corn from China which has a distinctly waxy endosperm.**

There is also great variation in the time required for maturity and in vigor and productiveness of different varieties under different conditions.

There are many well established varieties of each type of corn, all of which do well under certain conditions. The choice of a variety of corn is of much less importance than the improvement of the variety when once chosen.

Farmer's Bulletin No. 414 of U. S. Department of Agriculture says that little importance can be attached to varietal names since the seedsmen keep so busy interchanging them (or renaming) and the wind continually mixes varieties by cross pollination.

Vigor, or in other words productiveness, uniformity and adaptability to soil and climate are the important things to consider. It was the writer's experience under semi-arid conditions of Western Kansas that varieties grown there for a score of years would out yield newly imported varieties. Probably it will be equally true that varieties grown for some time in Hawaii will be better adapted to our conditions than any that can be brought in. Importation however should continue, but only upon a small scale, in attempts to secure better results. Larger yields are likely to be secured by later maturing varieties under good conditions. However where the supply of water is liable to be cut off by drought, early maturing varieties may excel.

THE SEED.

According to Farmer's Bulletin No. 415 good seed is seed that is adapted to soil and seasonal conditions, that was grown on productive plants of a productive variety, and is well matured and has been preserved with full vigor.

When seed has been selected, unless already well dried, it should be dried as soon as possible and kept dry. In colder climates corn containing too high a per cent of moisture is injured or killed by freezing. In any climate, it pays to take good care of the seed. Various methods of storing seed are in use. Braiding the husks of several ears together and hanging them in shed, stable, kitchen, or attic, is a very common method. Tying several ears on a string and suspending from a rafter is also quite common. In large seed houses the corn is usually placed on shelves, an elaborate system of which provides storage for an immense amount of seed. Protection against rodents and insects should always be provided.

As stated under "yields," the yield may depend upon the stand and the stand of course depends upon good seed. The better farmers of today are testing their seed to insure a good stand.

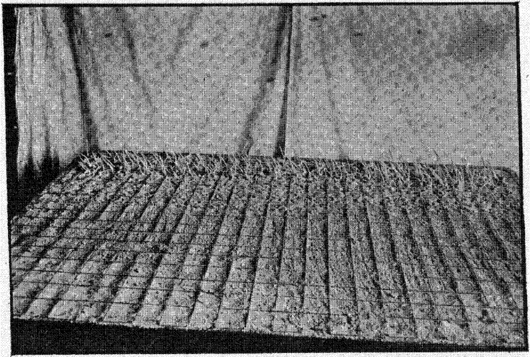

Figure 2: Seed Tester,—for testing individual ears of corn.

For shelled seed a good tester is made by using two ordinary plates and two sheets of blotting paper, or carpet paper. Place the seed upon one paper in a plate and cover with the second paper, put in sufficient water, and invert the second plate over this to prevent evaporation. Keep in a warm place. A more scientific method of testing is to test each ear. Take a shallow box 2′ to 3′ wide by 4′ or 5′ long and 2″ deep. Drive small brads or tacks into the edges at intervals of about 1½″ and with a string divide the box into 1½″ squares, as shown in figure 2 (first filling the box with sand.) With this, as many ears may be tested as there are squares. Place ears on shelves or tables in a long row, driving nails after each ten for convenience in locating the ears. Take from the ears, consecutively, three or four kernels from different parts and place, consecutively, in the tester and moisten and cover. With this simple contrivance any poor ears are detected and thrown out. All should come up at once; those coming first are generally supposed to be the better, but some experiments have given a slightly larger yield from those coming up last. After testing, the seed ears must be shelled, preferably by hand, but always discarding tip and butt kernels, which being odd in shape and size interfere with uniform work of the planter. Seed, from the tips especially, are thought to be less productive and are more likelv to be moldy and to have lost their vitality. In hand-shelling, any bad kernels, or ears having ill-shaped kernels may be more readily detected and discarded.

SOILS FOR CORN, AND PREPARATION.

Corn for its best development requires deep, fertile soil. The alluvial soils to be found in the river bottoms furnish ideal conditions for this crop. These would be described as silt loam soils containing more than the average amount of humus. Clay soils, when plenty of organic matter is turned under and mixed in, and when sufficiently well drained, will produce excellent corn. Sandy soils do not require the organic matter to ameliorate their physical condition like the clay soils; they need it to increase their fertility and moisture holding capacity.

Ordinarily deeper plowing is done for corn than for the other grains—the depth must be determined by conditions of soil and climate. Sometimes deep plowing would facilitate percolation and again, on thin soils, it would expose inert material. Whether to plow in fall or spring also is dependent on conditions of soils and climate, and upon the system of farming practiced. Listing, as explained under planting is a substitute for plowing. When double listing is practiced, the first listing is given in late summer or fall leaving the surface ridged and exposed until planting season, when the second listing destroys these ridges and creates others where the furrows were. On listed ground, if the furrows run nearly level, surface drainage is checked and water allowed to percolate; if the furrows run "up and down" surface drainage is aided and a loss of water results. With soils more or less granular in structure, as on the Great Plains, listing at right angles to the prevailing wind retards blowing. With floury soils, as in parts of Hawaii, less benefit would likely result.

The after preparation for corn depends largely upon the condition of soil after plowing. If the soil is exposed and left in large clods, these must be broken up by disc harrows. If the clods are small, a few days of exposure to sun and wind, followed by a harrowing with a spike-tooth harrow, will leave the ground in fair shape for planting. Except with the two horse planter which carries its own marker, or for grain drills, the field must be marked off for planting. By running a plank drag over the field or otherwise smoothing the surface, the track of a marker may be more easily seen. In the South many animals are trained so well that, with the one row planter, no previous marking is necessary, the animals keeping the required distance from each preceding row. For planting with the hand planters fields are usually checked with sleds having three or four runners spaced at proper distances for rows. Upon the return trip across the field each time, one runner follows the outer track of the previous trip so that all rows are at uniform intervals. For planting with hand hoes, the work is made easier if the field is marked with a small plow. The corn can then be dropped in the furrow and covered with the hoe, avoiding the necessity of digging a small opening for the seed or of planting right at the surface.

The season for planting, as stated, may vary. Corn requires higher temperature than do small grains, both for germination and growth, and makes its best growth in hot, humid sections. Cold nights tend to check its growth and hasten maturity. At higher elevations then it should not be planted until the nights become warmer.

PLANTING CORN.

The operation of planting may be performed by man and hoe first lining off the field in one or both ways accordingly as one desires to plant in checked hills or simply in drills. In this manner possibily one man can drop and cover two acres per day.

With a hand corn planter or "corn jabber" each man can plant 4 or 5 acres a day. With a single row, one horse planter, 8 or 9 acres may be easily covered while with a two row planter, 15 or 16 acres is a fair day's work. However, if the hills are "checked" with the latter machine slightly less can be accomplished. The checking device consists of a wire chain 90 rods long which has a sort of knot at regular intervals of 40"-44" throughout its length. The chain is staked at each end of the rows and as the team goes along the chain slides through the planter each "knot" opening the planting device. If the ground surface is level, and if the chain is so placed that the first hill of each row comes in line with the first hill of the preceding rows,—then when planted the field will be well "checked" and the corn may be cultivated in either direction. The chain must be reset after each trip across the field. Ordinary grain drills may be used in planting corn, using every fourth, fifth or sixth hoe only, stopping the others with pieces of cardboard or tin over the various openings in the seed box. The amount of seed used will be excessive, especially if kernels are small. Thinning the stand will be necessary. Sprockets for planting corn and beans in hills usually are sold with ordinary grain drills now. With these less thinning becomes necessary. Grain drills are much heavier than corn planters and require more power.

Listing corn is a practice common in the arid and semi-arid sections of the states. The ground may have been previously prepared by plowing or by listing but often such work is not done. The lister is a double moldboard plow like a "middle-burster." To this is attached a planting device similar to that upon ordinary planters. The corn is planted in the furrow immediately behind the plow. The soil here is moist but sometimes rather cold. Subsequent cultivation fills the furrow so that when corn is laid by the surface is fairly level. Listing is a substitue for plowing in which only about ½ (or less) of the land is really turned. If double listed the work more nearly corresponds to plowing. The advantages are that plowing and planting are done at one operation and the corn is in furrows protected from the wind while very small, and getting full advantage of all moisture. With heavy rains occurring while corn is small—especially upon heavy soils, the crop would be drowned out and would have to be replanted.

A special type of cultivator—called a lister cultivator—is necessary to work listed corn while it is small. With three horses, 7½ to 8 acres a day may be listed and with a double row lister, 15 to 16 acres should be planted in ten hours. Experiments to compare listing with surface planting result sometimes in favor of one method—and sometimes in favor of the other. The depth at which to plant is determined by the nature of the soil and the moisture content. Corn may be planted deeper in loose dry soil. The distances at which to plant must be determined by actual experience extending over several years. The fertility of the soil, its moisture holding capacity, the rainfall and the variety grown are factors which largely determine the optimum number of stalks per acre.

Hunt in his "Cereals in America" says 21,780 stalks in Connecticut, and 2,184 stalks per acre in Georgia are cited as having given best results. In Ohio about 12,000 per acre are usually planted, which is equivalent to three stalks per hill planted 3'x3'6"; or1'x3'6" in the drill, which is the rate over a considerable portion of the corn belt. In the South where soils are thin and hot dry summers prevail—single stalks 6x2 or 4x3 are usually planted, or 3630 stalks per acre. When the rows are placed 4½ to 5 feet apart, cowpeas in single or double rows are always interplanted.

CULTIVATION OF CORN.

The objects of cultivation are to conserve moisture and to prevent growth of weeds. The latter take up moisture and available plant food which should go to nourish the crop. Experiments show that no crop will be obtained where weeds are allowed to grow undisturbed. The preservation of a soil mulch to conserve moisture is more or less important where rain fall is deficient. In recent experiments, as good returns have been obtained by hoeing off weeds as by cultivating which proves that deep cultivation is unnecessary. Hoeing is expensive and the hard surface resulting does not readily allow percolation of falling water—so that cultivation is preferable. Deep cultivation seriously injures older corn and is unnecessary on young corn unless the preparation of soil before planting was poorly done. Ordinarily the first cultivation of corn is made with a light smoothing harrow. This is a cheap means of destroying weeds as they first start to grow and the corn being more firmly rooted is not injured. The next cultivation must be very thoroughly done with small shovels next to the rows—or with fenders used to prevent the covering of the corn but allowing enough dirt to be moved to cover the weeds in the row. If this is done at the proper time no hoeing will be necessary even for corn in drills. If wet weather prevents, the weeds get the start and are much harder to eradicate, in which case the corn in checks is more easily cleaned since it can be cultivated in two directions.

The two following cultivations throw a little dirt to the row and clean the middles—at the same time preserving the soil mulch. In case weeds get beyond control, a disc cultivator which will throw considerable dirt to the row may be the means of saving the crop. Ordinarily however it is best not to ridge the corn, since in a ridged surface more evaporation takes place. Where rains are too plentiful, however, ridging protects the corn. It is a common idea that ridging is necessary in places exposed to the wind, but such is not always the case. Where the wind has been continuous, where the growth has been medium rather than rapid, and where the ears are borne low, the corn is not easily blown down.

THE MOISTURE REQUIREMENTS OF CORN.

Prof. King, of Wisconsin, found that to produce 1 ton of dry matter in corn 270 tons of water were required, an equivalent of 2.4 acre inches. Hunt states that at the Illinois Station from 18 different varieties upon 18 tenth-acre plats, with a rainfall during the growing season of 13"—32 bushels of dry shelled grain was obtained per acre; while in the following year with same varieties upon the same plots, similarly tilled, but with 22½" rainfall, the yield was 94 bushels per acre. This shows a gain of 6.5 bushels for each inch of rainfall above 13". The distribution of rainfall is as important as the amount. From the time that the ears begin to develop any lack of moisture will be shown in the yield, and a full crop is assured only when corn receives a plentiful supply of moisture during this stage of its growth. Where it is known that rainfall at such time is not to be depended upon, conservation of moisture by clean shallow cultivation must be practiced. In some sections earlier maturing varieties may prove advantageous over later ones now grown, since the ears will be filling out at an earlier date, before the effect of lack of rain is felt.

FERTILIZING REQUIREMENTS.

Profitable crops of corn have been grown in Illinois and other states of the corn belt upon the same soil for as many as 60 years. This could be done only on a fertile soil, yet nobody at this time is ignorant of the fact that such a practice results in depleting the fertility of the soil. According to tables in Henry's Feeds and Feeding a ten ton crop will remove 58 lbs. Nitrogen, 22 lbs. phosphoric-acid and 78 lbs. of potash. Where only the grain is removed, the figures would be 46, 20 and 16,—much of the potash being found in the stover. Such a drain upon the fertility for a score or more of years would ruin any but the best soils.

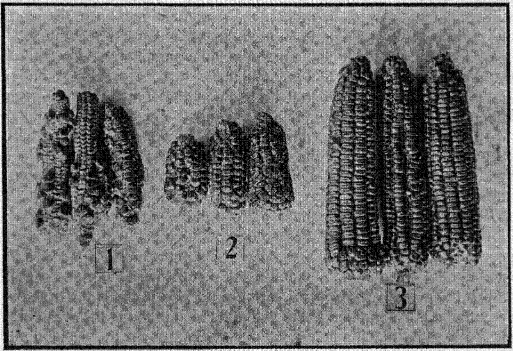

Figure 3. Effects of Fertilizer upon Corn (Kauai):
1. No fertilizer.
2. Vegetable fertilizer.
3. Barnyard manure.

Barnyard manure has been found to be the best fertilizer for corn. Organic mater in any form increases the production. Where rotations are practiced, the manure is applied to old meadows and the stubble and roots there found also help to increase the amount of organic matter. Commercial fertilizers are of value, but not to the same extent as for small grain crops. This is true also upon Hawaiian soils. Fig. 3 shows the results of manure, and of commercial fertilizer upon corn grown on Kauai. When fertilizers are applied, one analyzing 8 to 9 per cent phosphoric acid, 1 to 2 per cent. nitrogen and 2 to 4 per cent. of potash is usually recommended, in applications of 200 to 400 lbs. per acre.

ROTATIONS for corn are various because of the great variation in crops grown in different places. Rotations generally consist of corn, some one of the small grains, and hay crops, including a legume for enrichment of the soil.

In the Northeast states corn occurs in rotations with oats and with timothy mixed with clover. In the Southern states corn and cotton occur in two year rotations, cowpeas being planted in the corn. In some sections a three year rotation is practiced, winter oats followed by cowpeas being included with the corn and cotton.

In Hawaii corn may be grown as an annual crop—but in rotation with such winter crops as oats, wheat, rye, barley, either alone or mixed with some such legume as red, alsike, crimson or burr clover (1) or with cowpeas, velvet beans, vetches.

Above or near the frostline, some one of the small grains, with a hardy legume such as the clovers and vetches, could be grown and pastured off and cut for hay, or turned under for green manure.

In the central West, wheat often follows corn, being planted in the standing corn in September or October. For this purpose a small, one-horse, five disc drill costing $12.00 to $15.00 is used. Wheat makes excellent pasture during winter months and a fair yield of grain in the summer, additional. Probably rye or wheat will prove more valuable for early planting in corn, and oats or barley for late planting. Seeds of all of the legumes are very expensive and this fact, together with the uncertainty of obtaining a full stand accounts for the rare use of legumes as winter crops. Small grains, however, should be grown whereever possible to prevent leaching or blowing of the soil, and to furnish pasture and green manure. The only objection that can be given to their use is that to obtain full value for them, only spring plowing is possible and even this must be postponed until the last possible moment—thus making an excess of work to be done within a comparatively short time. Fall and winter plowing are thought to be necessary for some soils—to allow for action of frost and to permit percolation of rainwater. The growing of a winter cover crop accomplishes practically the same result in milder climates—the roots improve the physical condition of the soil, the tops induce percolation by preventing surface drainage; and the cover crop has two advantages in that it also prevents leaching of plant food during heavy rains and furnishes material for green manuring.

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(1) Clovers should be first tried out upon a small scale and their value for the given conditions determined.

INTER-CROPPING.

In parts of the South, or upon some soils where, because of thinness of soil and danger of drought, more space is allowed individual plants—the intervening spaces are to some extent filled by planting cowpeas. On richer soils, where moisture is plentiful, the same practice obtains, notably in the cane sugar districts of Louisiana. The cowpeas may be scattered and covered when "laying by" the corn or they may be planted in rows between the corn with the one-horse corn planter. Soybeans, Jack beans, velvet beans, garden peas, navy beans, dwarf Lima beans or other garden or truck crop might be similarly planted for enrichment of soil, and for food purposes. As stated under the subject of rotations, small grains are likewise planted between rows of corn. In the North, prior to the days of the corn harvester, pumpkins were well esteemed as a plant to grow with corn.

DISPOSAL OF CORN STALKS.

When uncut stalks are fed as a soiling crop or as stover, there is considerable waste in the large part of the stalk uneaten—much more of course when the dry stover is fed. When the stover is shredded or the fodder cut into silage, the per cent. of waste is but very small. If fed to the cattle in pastures the waste may be distributed by feeding always in a different place. When fed in stables or feed lots the waste material must then be hauled out and scattered where wanted—usually upon the cultivated fields. When left in the field standing, the stalks are grazed, broken and trampled down by the livestock which are usually turned in to feed upon leaves and immature ears, grass, etc., in the field. The pasturing of corn stalks is attended with some danger. Epidemics of cerebro-spinal meningitis (corn-stalk disease) have occurred quite frequently in late years. Particularly, when wet, and the leaves and immature ears become moldy—and when the stock have access to no green feed, is there danger in such pasturing. Care should be taken to first turn stock into corn fields only when they have full stomachs—to prevent overfeeding upon the unaccustomed dry material.

Whether pastured or not, there is a large amount of material left upon the field, the disposition of which varies in different regions. Usually to flatten down the stalks a heavy timber 16′ to 20′ long is dragged across the field, taking several rows at once. With level smooth fields longer timbers with a team attached to each end may be used. In early morning when the ground is frozen slightly is considered the proper time for this work in the corn belt. The next step is to rake the stalks into windrows with a hay rake and burn them, after which the ground may be more easily plowed and prepared for the following crop.

Where wheat has been planted in the corn, the stalks are not burned but are left and turned under when plowing the wheat stubble.

To avoid the loss in vegetable matter caused by burning, stalk cutters are now coming into use and except where the mass of material is excessive, they so cut the stalks that the pieces are easily turned under with the plow. These implements are made in one-row and two-row styles and have several blades on a revolving head—the blades cutting the stalks against the soil, which must be rather firm, into pieces perhaps 8″ long.

THE MAINTENANCE OF THE FERTILITY OF OUR CORN LANDS.

In Hawaii where there is a limited area adapted to the production of corn the maintenance of fertility is important. As stated under the subject of fertilizers, organic matter is very valuable. The destruction of organic matter by burning should in no case be allowed. The practice is common in Kula but should be changed. All of the stalks and all manure obtainable should be turned under to form humus. Legumes should be grown to aid in replenishing the supply of nitrogen. The Cornell station has demonstrated that the legume crop fertilizes the non-legume crop, when the two are grown together, as well as storing up nitrogen for future crops. Winter cover crops to prevent leaching, washing, or blowing, and to be plowed under for green manure, are invaluable. Longer rotations, in which corn appears not more often than once in two or three years, should be tried, if the other crops can be made at all profitable.

The keeping of livestock, the feeding of the field products, and the sale of finished products rather than of raw materials, are well recognized methods of avoiding depletion of fertility. In case of the sale of products which are grown at great expense of fertility, some return should be made by purchasing or growing fertilizing materials to make up for the loss.

HARVESTING CORN.

The time of harvesting or stage of maturity depends upon the product desired. For silage, corn is cut while still green. For grain only, corn is left until some time after becoming mature. For grain and stover, corn is cut when lower leaves are drying. For more grain than stover, leaves or tops may be removed while yet green, but the stalk and ear left until later.

There are several different methods in vogue in the United States for handling the corn crop, and in some cases the work is divided, the grain and roughage being harvested separately.

In the South there is much less livestock kept than in the North, and but little of the roughage is harvested. In some sections it is the custom to go through the fields just previous to the time when the leaves begin to dry and strip them from the stalks. Small bundles of these leaves are hung to stalks to dry, after which they are stored for feeding. The leaves when saved thus make valuable feed, but the process is an uneconomical one.

Another method practiced in some sections is, when the lower leaves have dried, to go through and cut off the stalks just above the ears. These tops are tied in bundles, shocked for a time to dry, then stored for future use. This feed is less valuable than equal weights of "pulled fodder," and the amount of labor involved makes the feed expensive also.

In all sections of the South the corn is pulled from the stalks with ¾ or all of the husk left on to protect the corn from weevils. To safely store corn in the husk or "shuck" it is necessary to allow it to become thoroughly dry before harvesting. The corn is fed in the ear, the husking being done at the time of feeding. After the corn is harvested, livestock are usually turned in to get what feed they can from the standing stalks and from cowpeas which are usually planted in the corn.

In the Northern states, East of the corn belt proper, it is the practice to cut and shock the entire plant at first signs of maturity, or when frosted, but preferably a few days before frosts are to be expected. After curing for six or eight weeks the corn may be husked from the shocks or the shocks may be hauled and stored and the husking done at odd times during the early winter months. An active man can cut and shock an acre a day, except in very heavy corn. A "shocking horse" or "corn saddle" is used. The former consists of a 1½"x1½" x18' pole, supported at one end by two diverging legs at a height of 3' to 5', depending upon the height of the corn. A few feet back from these supports a slender iron rod 4' long passes through a hole in the pole. In the angles thus made the corn is shocked well bracing the stalks toward the center; the shock is tightly bound near the top, the rod is removed, and the horse is then carried forward for the next shock.

The corn saddle is made by bending the stalks from four hills, situated at the corners of a square about 3½' on a side, toward a central point and tying one about another until a support is made against which the corn is shocked as above described. When removing such shocks however, it is first necessary to locate and sever the stalks of the support which were not cut at harvest time. Shocks made by this method retain their shape and preserve the corn usually better than those made by the first method, especially in stormy weather. The feed loses value so quickly in such weather that the aim is to get it under cover as soon as possible and the former method entails less labor both at harvest and hauling time.

From 25 to 50 shocks are made per acre depending on the amount of corn there is present and the stage of maturity and weather conditions. With drying weather and corn nearly mature larger shocks may safely be made, while otherwise small shocks should be made. Where the corn is to be fed to fattening cattle the entire plant may be fed without any husking.

The stover, whether the husking has been done in the field or in the barn is fed out to livestock during the winter, most of the uneaten portion being returned to the land with the manure. Within recent years the above method has been modified by the use of huskers and shredders. These are power machines which remove the ear from the stalk and husk it, and shred the stalks and leaves, delivering corn into a wagon and stover into barn or stack. In this way much hand labor is avoided, the work of husking is not drawn out for several weeks, and the resulting feed is more completely consumed.

Shredded stover, unspoiled, makes excellent feed, provided the corn was not damaged by too long exposure in the shocks. When shredded, the stover is easily spoiled by molding unless perfectly dry at time of shredding. The writer recalls that three methods were used to avoid loss by molding:—(a) if possible to shred at intervals of a few weeks so as not to have the shredded stover in too large piles; (b) to mix oat or wheat straw with alternate layers of the stover; (c) to shred only in cold weather and when stover was perfectly dry.

In this same region also it must be remembered that the silo is in common use for preserving a part of the corn crop. For cutting the corn for silage and to some extent also for cutting it for the shock, the corn harvester is now in use, but the cost of cutting has been reduced only slightly. For silage late maturing Southern varieties have been used but the silage therefrom was very "sappy"; ordinary late varieties, if cut at the proper time, make about the same amount of dry matter per acre.

In the corn belt proper, the acreage in corn is so large that the harvesting of the entire crop would produce an unnecessary amount of feed and the work of saving it would have been almost impossible in many cases. Some corn is placed in silos, some is shocked and possibly shredded, but over by far the larger area, the corn is husked from the standing crop, after which livestock are turned in to pick up what they can. For this work the wagon is fitted with an ordinary double wagon box (holding about 50 bu. of wheat) along one side of which boards or a woven screen on a frame is erected, making the side about four feet higher than the opposite one. The corn is thrown against this "throwboard" or "bump board" by the husker (who seldom glances at it) and falls back into the box. The wagon box is also fitted with a hinged rear end-gate, in place of the regular one, known as a "shoveling board" or corn end-gate. This can be dropped to a horizontal position and shoveling commenced at once without any hand work, when the crib is reached. The capacity of these boxes is figured as one bushel for every inch in height, plus four for the shoveling board which lengthens the box a few inches. A 36″ box would hold 40 bu. A steady team that will follow the row and start and stop when told is necessary. After a few days at the work, the team usually walks along slowly, nibbling at the corn stalks, and pulls the wagon about as fast as the operator can husk his two rows, without command from him. Ordinary husking pegs of wood or metal are used in the hand but for rapid work a hook held by a strap near the base of the thumb is used. With this, experienced men rip off the husk, snap the ear, and throw it in the wagon at a single motion. Such men, in good corn, husk from 75 to 90 bus. per day, while from shock corn, 35 to 40 bus. is considered a good days work. Corn must be well dried before husking if large amounts are to be stored in one crib.

THE CORN SHOCKER is similar to the corn harvester in some respects, but at the rear of the machine is a platform upon which the fodder is shocked. When the shock is completed the team is stopped, the shock raised by tackle and set upon the ground at one side, after which the machine is again started. This machine is not in very common use although successful in operation.

THE CORN PICKER, an implement for picking the ears from standing corn, is not as successful as the preceding and is rarely found.

THE SLED CUTTERS. Besides the machetes, or cane knives, and the corn binders in use for cutting corn, sled cutters are sometimes used. The essential principal of this is a strong cutting knife held horizontally but at an angle of 45° to the row of corn to be cut. As the knife is pulled forward, upon sled or wagon ,the blade makes a "draw-cut" severing the stalks of corn. Some sleds are equipped with two such knives, so that two rows may be cut. Some, again, have seats for two men who catch the stalks as cut and drop them off in bundles. For cutting for silage, the writer once worked upon a low "handy" wagon equipped with such a blade; one man stood behind it and threw the stalks, by armfuls, upon the platform of the wagon, while another, or perhaps two, aided in arranging the load.

STORING THE GRAIN.

As mentioned above the corn is, in some regions, stored with the husk left on, and in others, free from the husk. The protection from weevils, which the husk gives, may be attained by drying the corn in a kiln after the manner of drying hops. When thus dried the outer hull is so hard as to in large measure protect the corn.

Upon the smaller farms of both North and South, corn is stored in long, narrow cribs, having slat sides to allow for proper ventilation. Slat bottoms are sometimes built. In some cases the crib may be a part of the feed barn, a part of a general granary, or it may be a structure put up expressly for corn. Usually granaries or corn cribs are permanent structures raised from the ground 3½′ to 4′ on 8″x8″ supports, over which tin pans are inverted, or other device employed, to keep out rodents. In the corn belt proper, large permanent cribs are employed, particularly in the humid sections. Besides these, and more especially in the semi-arid sections, temporary cribs are in use. For these a closely woven wire fence, a special weave of woven wire for crib purposes, or a special weave of slat and wire fencing, is necessary. In constructing the crib, two posts 6″ or 8″ in diameter are set in the ground 4′ apart. If 4 foot fencing is used, the posts must extend 8′ above the surface when set. The posts must be well bound together at the top. One post would answer the purpose of holding the wire erect, but with two, the space between is boarded up when filling, with light boards which are easily removed and this space used as a doorway when corn is to be moved. The cribbing is made in certain lengths and the fencing may be cut to make a crib from 12′ to 25′ in diameter, as wanted. After stapling the wire to the posts, a rough floor is constructed, yet it should be sufficiently smooth to allow for use of scoop shovels when removing the corn. When filling, the wagons must not be unloaded at the same place each time, but at different places, so that the crib will retain its upright position. When filled to the height of the wire, another section is placed directly above and wired to the lower one. Then when filled heaping full, rounded towards the center, a canvas may or may not be thrown over the corn for protection. Unless to be shelled soon some sort of roofing is necessary.

SHELLING THE CORN.

Upon small farms hand corn shellers are in use and also much of the corn is shelled at the mills where it is ground into meal. Individual farmers cannot afford the sheller and power, so the miller is equipped for the work. In the corn belt, large corn shellers with a capacity of 1500 to 2500 bushels, or more, per day, operated by steam power, go from farm to farm, much as the steam threshers do in the wheat belt; in fact in many localities the shellers are owned by threshermen. (Silage cutters are owned and operated in a like manner in other sections.) After shelling, the corn may be held for feeding purposes in bags or bins, or stored in grain elevators, as with small grains. When stored in bulk, moving from one bin to another is sometimes necessary if the corn is found to heat.

SHRINKAGE AND LOSS.

In silage, in the best silos, there is a loss of from 5 per cent. to 10 per cent. in total dry matter due to the carbon dioxid evolved. If kept for some months the loss will be still greater. In field curing, an average of about 20 per cent is lost. The loss in each case is in carbohydrates other than fiber.

There is a reduction in yield of grain amounting to 2 or 3 bushels per acre ,where attempt is made to save leaves, tops, or stover for roughage. The shrinkage of ear corn in the crib varies from about 5 per cent. to 25 per cent., with 15 per cent. as an average for average conditions. After shelling, the corn may still shrink somewhat, but most of the shriinkage occurs in the cob, which from being 1-4 of the weight is reduced to about 1-5, and loses 10 per cent. in length and circumference.

WEIGHT.

56 lbs. is the commonly accepted weight for shelled corn; 70 lbs. for corn in the cob after curing; and 70 to 80 lbs. for green corn.

YIELDS.

The following factors are the chief ones in determining the yield of corn:

1. *The fertility of the soil,* which in turn depends upon the depth of soil, the amount of humus, the physical condition of soil, whether the conditions therein are suitable or not for bacterial action.
2. *The moisture conditions,* as influenced by the water content of the soil, its water holding capacity, the amount and distribution of rainfall (or of irrigation or of sub-irrigation) and the amount of loss by evaporation or by weeds, (the number and thoroughness of cultivations.)
3. *The kind or species of corn and the variety,* its adaptability to present conditions or environment.
4. *Climatic influence;* the length of the growing season, the average, maximum and minimum temperatures, the day and night variations, and rainfall (2).

5. *The thickness of the stand,* the optimum number of stalks per acre for the given conditions and variety. A poor stand is very often the cause of reduced yields. Whether it be caused by insects, by poor seed or by too thin planting, the cost of caring for the resulting crop until harvest is the same as if the stand were perfect, therefore every effort should be made to keep down cost of production by having only good stands. Too many stalks per acre likewise results in reduced yields, i. e. of grain; the number of pounds of dry matter per acre might be increased.

The Yearbook of the Department of Agriculture gives the average yield per acre of the United States for 1911 as 23.9 bushels, the highest average yields being in the North Atlantic states (42.4 bus.) Texas and Oklahoma had 9.5 and 6:5 respectively. (In these latter states the soil is fertile enough but the rainfall is deficient). Connecticut leads the list with 48.5 bushels. Average yields, however, give one no idea whatever of what ordinary, possible, or maximum yields might be.

In the contest conducted by the American Agriculturist in 1889, a man in South Carolina produced 255 bushels of ear corn upon an acre. Incidentally, 1000 bushels of manure, 600 bushels of cottonseed, and 3600 lbs. of guano, cottonseed meal, kainit, acid phosphate, bone, and nitrate of soda were applied to the acre at different times.

Less than 30 bushels must be considered poor yield on good soils; 40 to 60 bushels are good yields, while 60 to 100 bushels are extra good yields.

In estimating green forage, a crop that will make 60 bushels of grain is calculated to make 12 tons of green feed per acre, a ratio of 5 to 1. This factor, while generally accepted in the corn states, doubtless varies. According to a test of a trial row made by the writer, the factor was 6 1-6 bu. to a ton of green feed. With this factor a 60 bu. soil will yield 9.73 tons of green feed.

FEEDING CORN.

1. As a soiling crop. In the Northern states in many places the summers are dry and hot and consequently the blue-grass pastures are usually cropped rather short and the grass ceases to grow until the fall rains come. Under such conditions or where, for any other cause, a shortage of feed in summer re-

sults, it is quite a common practice for farmers to cut daily some of their corn and feed it to the stock to supplement the pastures. Particularly is this done for dairy cattle. If it were not done, the flow of milk would be reduced and could not in the fall be increased to the proper amount.

Some dairymen, near cities where land is very valuable, make a practice of soiling their cattle at all seasons, since in cultivated crops much less acreage is required than in pasture.

2. As silage. (See Press Bulletin No. 40). The feeding of silage is becoming more common as time goes on, and the value of silos and silage better appreciated. Silage is a succulent feed, available when other such feeds are wanting, and hence of great value. In experiments with milk cows, silage produced from 5 to 11 per cent. more milk than an equal weight of fodder, cut and allowed to dry in the ordinary manner. In is only with fat steers on full feed that the superiority of silage is questioned. In the corn states it has been valued especially as a winter feed, but is being used more and more also as a summer feed. In Hawaii silage would be valuable indeed to cattlemen during long periods of drouth.

3. As stover. Reference has been made to the use of leaves and tops in certain sections, and to stover, whole, or shredded, as used in various regions. That the stover is of considerable value as a feed may be seen by noting its composition given on page 1. Much more livestock may be kept, and better farming done, where the whole feeding value of the plant is realized.

4. As fodder. That is with the ear still on the stalk. This is done in some sections where labor is scarce. The cattle get roughage and grain at one time and the labor of husking is avoided. In such cases hogs usually follow the cattle to prevent waste.

5. As a grain. Corn may be fed upon the ear, with or without the husks, shelled, ground with or without the cob, ground with or without other grains, soaked or even cooked.

The value of corn as a feed is so well known that no statements of it are necessary. For sheep, lambs, pigs, dairy cows, beef cattle, poultry, fattening horses, or for work animals, in fact for all classes of animals, of all ages, regardless of the purpose in feeding, corn in mixtures, or alone, acknowledges no superior. Even for man, corn as a food is important.

From the table of composition it will be seen that corn is especially rich in nitrogen free extract or in other words in non-nitrogenous constituents. For this reason some material containing larger quantities of nitrogen is usually fed with it. Clover, alfalfa, cowpeas, soy beans and peanuts are used as roughage in dry or green state.

For concentrated feed, linseed or oil meal, cottonseed meal, the seeds of cowpeas, soy beans, peanuts, etc., are used to balance up the corn in rations. More economical gains are made when balanced rations are fed. For instance, when hogs have access to alfalfa hay, the amount of corn necessary to produce a lb. of gain is reduced from 5 to 7 lbs. to about 4 lbs. With clover or cowpea hay replacing timothy a bushel of corn produced 1.65 lbs. beef more than with the timothy hay. In a similar case, the output of milk was increased 20 to 33 per cent. Other examples could be given, but these are sufficient to demonstrate the point that balanced rations are more economical. Corn is considered a very heating food and in the Northern States is fed to work horses in the colder months, oats being reserved for the summer months. when the work is more severe. However in the South oats are less profitable as a grain crop and are usually cut green for hay. Moreover the acreage in oats is very small. Corn is fed to work stock the year round with no bad results, nor with any complaints as to its being a "heating" feed. "Corn chop" is a term which in the South usually applies to coarsely ground or cracked corn. In the North, the same term applies to a finely ground mixture of corn and oats, or corn, cob, and oats. Grinding the corn increases its value as a feed for hogs and cattle, more rapid gains on less grain being usually (not always) obtained. Where hogs follow cattle but little gain is obtained by grinding, and by feeding whole grain, much labor and expense is avoided.

CORN AND COB MEAL. Cobs may be ground with the corn under certain conditions and for certain kinds of stock. For hogs the cobs should not be included. For a few months after harvest, while cobs are still more or less soft, they may be used, but in late Spring months and in the following summer, few farmers feed corn and cob meal. According to Henry (Feeds & Feeding) theyserve to lighten the otherwise heavy mass of corn meal, making it more easy to digest. The actual value of cobs is very, very small.

Ground corn, whether with or without the cob, and especially when ground with oats, heats readily and cannot safely be stored in bulk. Only small amounts should be ground at any one time. After grinding, also ,the oil "soon becomes rancid and gives the meal a stale taste." Soaking the corn or corn meal is more or less practiced, and is thought to increase its feeding value, especially for hogs. In Kansas a gain of from 5 to 15 per cent. was obtained by soaking corn for steers. In Germany sheep on dry grains increased 12.1 lb. more in 14 weeks than those on wet grains, the lack of gain in the latter being attributed to a decreased secretion of saliva. No advantage was found in soaking the grain for horses.

The chief value of corn is in producing "heat, energy, and fat." Because of its deficiency in protein and ash constituents, it is not a perfect food for young growing animals, nor for breeding stock. The deficiency must be supplied in other feeds.

CORN AS FOOD FOR MAN AND ITS USE IN MANUFACTURES.

Corn meal is a valuable food for man and the annual consumption of corn as bread, cakes, or mush, is quite large. Freshly ground meal is much superior for culinary purposes.

Food products other than the meal are roasting ears, hominy, corn combined in various breakfast foods, canned corn, and corn starch. Manufactured products include glucose, starch, alcohol, whiskey and malt liquors, and corn syrup, with which is usually mixed some ribbon cane syrup to improve its flavor.

The by-products resulting include: oil, gum, dextrins, germ oil meal, gluten meal, bran, gluten feed (meal and bran), distillers' and brewers' grain, hominy feed, cerealine feed.

The pith of the stalk is used for packing and in the manufacture of explosives, the balance of the plant in this case being ground, forming a good substitute for hay, under the name of "new corn product." The composition of the by-products is given by Hunt as follows:

	Water	Ash	Protein	Crude Fiber	Nitrogen Free Extract	Fat.
Gluten meal	9.2	1.1	36.9	2.2	46.7	3.9
Maize bran	9.1	1.3	9.9	12.1	62.0	5.6
Gluten feed	8.5	1.2	25.7	6.7	53.5	4.4
Germ oil meal	9.1	2.6	23.0	9.0	45.6	10.7
Hominy feed	9.3	2.7	11.2	4.5	63.7	8.6
Cerealine feed	10.2	2.6	11.2	4.6	63.3	8.1
Distillers' grains	8.8	2.4	35.	12.1	30.4	11.3
New Corn Product	8.5	5.4	6.5	27.3	49.3	2.9

THE POLLINATION OF CORN.

The pollination of corn is effected by wind and by the force of gravity. The tassel is the male portion of the flower, while the female portion is borne in the axils of the leaves. The silk is the "style" of the pistillate flower and is supposed to be a long tube down which the pollen grain must pass to reach the ovule. To effect pollination the silks must be at a certain stage of development when the pollen is available. Ears having no grains at butt, or at tip, show that the silk of butt and tip respectively was immature or past mature and were consequently not pollinated. If such barrenness is noticed to be very common it can in part be corrected by planting rows here and there across the field either earlier or later, as the situation demands, to furnish pollen at the proper season or to lengthen the season in which mature pollen is available. Rarely does one see an ear entirely barren of kernels, but isolated stalks on windward sides of the field in regions of continual wind occasionally produce such ears. Short ears result from poor conditions of environment, not from imperfect pollination. Barrenness also is largely the result of environment—too thick a stand, weeds, poor soil, or lack of moisture.

Suckers very often produce hermaphrodite or perfect flowers. Tassel ears also result from perfect flowers in the tassel. Such ears, or the tendency to form such ears, is undesirable. Avoid these plants when selecting seed.

CORN IMPROVEMENT.

Some of the greatest strides in recent agricultural science have been made in the various states in the work in corn improvement. The work is divided into two branches, viz: seed selection and breeding.

SEED SELECTION is based upon the law that "like produces like," and if good corn is to be expected good corn must be planted. Following this idea, intelligent farmers have selected their seed corn for many years. Now, however, it is known that excellence in plants may be due either to heredity or to environment, and seed selection becomes more complicated in that an effort must be made to secure the corn whose excellence is due to heredity. That which is due to good conditions of environment, cannot be continued unless the same good conditions are always present. To accomplish the desired result, it becomes necessary to select seed corn from the field where one can know what the environment has been. For illustration, we will suppose two hills of corn, one containing one stalk and the other two, both of which produce one good ear. In the hill which has two stalks, the one producing the ear possesses excellence over the barren stalk due to heredity—or otherwise we should find the ear upon the other stalk or one small ear upon each. The ear from this stalk also would be superior as seed to that from the other hill which contained but one stalk, since in the "struggle for existence" a great handicap was overcome in producing it. Such conditions as plenty of space in which to grow, advantage in fertility of soil, or in excess of water, or in freedom from weeds result in producing good ears whose excellence may not be continued when again planted.

Selection in the field then enables one to see under what conditions the ear was produced and to note also the character of the stalk and leaves of the mother plant, size and weight of ear, maturity, color ,also broken plants or tendency to sucker, and the height of the ear upon the stalk. High ears tend to pull stalk down and the selection of such tends to produce a late maturing strain. For windy places select seed from short, thick stalks, with ear rather low.

The Ohio Experiment Station (in Bulletin 212) reports upon seed selection as follows:

A gain of 4 to 5 bushels per acre when seed was taken from long ears over that from short ears; one bushel, when cylindrical ears were used as compared with tapering ears; the same gain when ears filled to the tip were compared with those having bare tips; 2 to 3 bushels, when smooth kernels were compared with rough; and 4 to 5 bushels gain with heavy ears over light.

This gives an indication then of some points to observe in making selections. Weakness of stalk, as indicated by broken plants, and suckering (in part only) are heredity traits and seed from such plants should be avoided. Prof. Krauss, of the College of Hawaii, found in an ear-row test with one variety, a great variation in the tendency to sucker.

The work of selecting in the field may be done by some one well qualified for the work before the regular harvest is commenced, or, with intelligent laborers, or where the farmer himself does part or all of his work, the same result is accomplished at harvest time by having a box hung on the rear end of the wagon in which choice ears may be thrown when found.

Usually two or three times as many ears are taken as would be necessary and later a more careful selection is made from among these. The germination test also may eliminate some ears and so plenty should be taken out at harvest. In the corn states it has frequently happened that the seed of some seasons was very low in vitality and those who had seed saved from the preceding year were fortunate.

The second step is the proving out of the seed selected. Although each of the ears selected are excellent and this excellence is hereditary, yet each one has inherited a different producing power and each must be planted by itself in order to determine which are the better producers. This test is known as the "ear-to-row" or simply "ear-row" test. Upon the windward side of the field plant about 100 feet of row from each of 25, 50 or 100 ears, and duplicate the test if possible. Duplication of the test and the planting of every fifth or sixth row to corn of known producing power as a check, are methods in vogue to determine variation due to different conditions of environment. Have such conditions as uniform as is possible.

The balance of the selected ears are used in planting the main field. For the second year, the seed is selected from the high yielding corn as determined in the ear row test—while many choice ears are taken from the main crop and planted in another ear row test to compare them with the high yielding ears of the

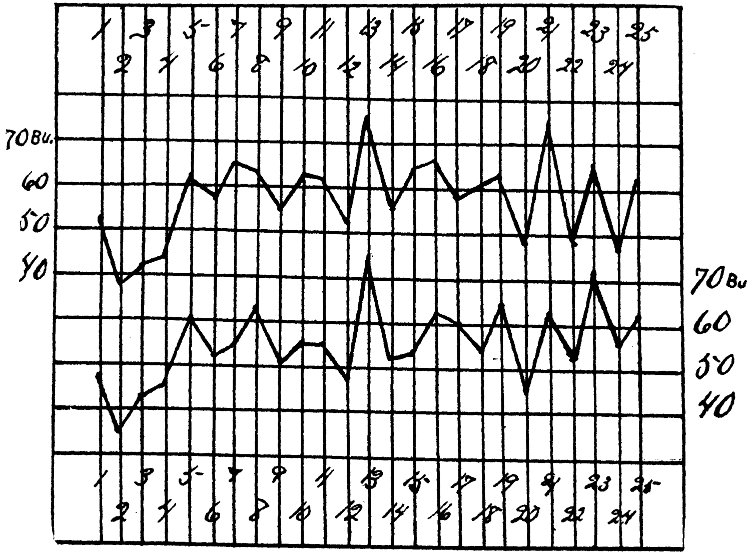

Figure 4: from Ohio Station Cir. No. 66.

The result of duplicate ear row test made by F. C. Snyder of Ohio. Thirty-five to seventy-five bushels per acre.

This test was made in 1904, the remnants were placed in the breeding plot in 1905 and in 1906 the yield from the improved seed exceeded that from ordinary seed by 7.17 bu. per acre.

How else could the excellence of ear No. 13 over ear No. 2 be determined?

previous test. It is not to be expected that all of the high yielding ears are obtained in the 100 that were first selected out of the hundreds, thousands, or perhaps millions of the whole crop—or even that the very highest yielding ones were obtained, and therefore year by year search for these latter should be made by selecting always some from the main crop for test. Seed for the main crop however should always be taken from corn that has been tested and found to be good in yield.

For large areas where the ear row test would furnish an insufficient amount of seed—some seed from the general crop could be used, but a separate plot for producing seed would be preferable. Right here the line between selection and breeding is not closely drawn. As corn is readily cross pollinated, cross breeding occurs in the ear row test, so that while the aim was only to test the different ears the resulting progeny may be better or worse than the parents according to the nature of the cross-breeding which has occurred.

BREEDING.

Under this heading then we shall consider the more complex methods which involve the use of breeding and multiplying plots. For breeding work the primary selection and the ear row test are made as above described, with the exception that portions from each ear are reserved, properly labeled, until the result of the test is known. The breeding work proper starts with the remnants of ears found to be high yielding; the other remnants are discarded.

The following scheme from Ohio E. S. Circular 66 shows the plan to be followed:

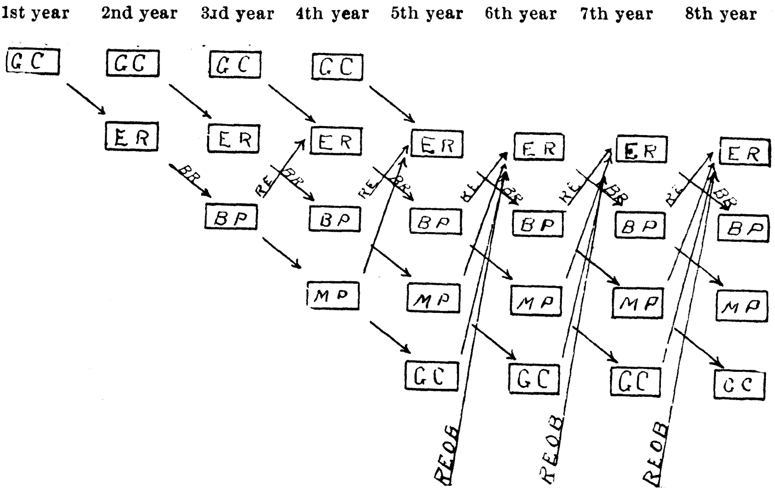

Figure 5:
A scheme for breeding corn—from Ohio Station Cir. 66.
GC—general crop. BR—remnants of best ears. ER—ear row test. RE—registered ears. BP—breeding plots of remants. MP—multiplying plot. REOB—registered ears from other breeders. The arrows show the source of seed for each plot or field.

The ear row test may be placed in the main field but the breeding plot and multiplying plot must be isolated to prevent cross pollination with pollen from undesirable plants.

In the breeding plot, natural methods may be allowed or certain rows may be detasseled and the seed taken from the cross bred product of these rows. Cross breeding increases vigor, and (also to prevent inbreeding) outside blood may be introduced, after being tested in the ear row test, and its influence made certain by detasseling either the old or the new stock as stated. Outside blood is secured in selected ears, or pedigreed ears, from neighbors or others, breeding the same variety. The scheme shows how, after only four years work, the main crop can be grown from selected, improved, seed. Some such scheme as this is necessary if there is to be any improvement made in the yield of corn. The use of isolated breeding plots eliminates the bad results obtained by cross pollination from low yielding or barren stalks. These qualities are, for the most part, hereditary and cannot be entirely overcome by good conditions of environment.

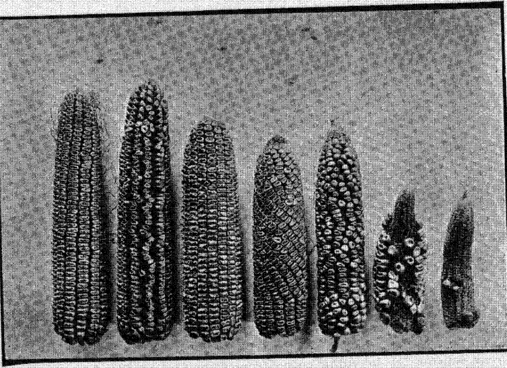

Figure 6. Types OF EARS.
1. Tapering—with wedge-shaped kernels.
2. Tapering—with oval kernels and too much space between rows.
3. Cylinrical—well filled at butt and tip—the "show" type.
4. Shows spiral rows.
5. Shows broken rows.

6 and 7. Show imperfect pollination.

Breeding, as applied to corn, means simply control of parentage, much as is the case in the breeding of animals. Hand pollination is rarely done.

IMPROVEMENT IN QUALITY.

In the above discussion of improvement, increase in yield only was considered. To increase the content of protein, starch, or oil, a similar method would be followed, selecting for seed in each instance those kernels which show the desired characters, as explained on page 2.

JUDGING CORN.

At the corn shows now being held in the various states and at the National Corn Exposition, corn is judged entirely by the ears—stalk and leaves not being considered. Usually ten ears constitute an exhibit and they are judged according to the following points:

1. The shape of the ear. This should be cylindrical or but slightly tapering.
2. Color of cob—a red cob for yellow corn and either white or red for white corn.
3. Tips. The tips should be well covered, the rows unbroken to the end.
4. Butts—well rounded, the shank 1-3 the diameter of the ear.
5. Kernels—deep, wedgeshaped, leaving no spaces between the rows. They must be firm on the cob and well filled.
6. Length and circumference of ear—the length varies in different varieties, but averages 9″; the circumference should be about 3-4 the length.
7. Uniformity—in shape and size of ears. In shape, size and color of kernels.
8. Condition—of ripeness, freedom from disease or injury, dry, firm.
9. The per cent of grain to ear—should be about 87 to 88. This point is not always considered.

Figure 6 shows ears of various shapes; rows of kernels straight, curved, or mixed; and ears well or poorly filled at the butt and tip.

Various sizes and shapes of kernels are illustrated in Figure 7.

INSECTS AND DISEASES.

(See Bul. Haw. Exp. Sta. No. 27)

The more common insect pests of the corn plant in Hawaii are the army worms and cut worms, which destroy the crop usually while young, and aphides and leaf hoppers, sucking insects which when found in large numbers soon destroy the crop at any stage of its growth.

The worms are best controlled by using poisoned bait (white arsenic 1 lb; bran 30lbs.; molasses 1 qt.; water to moisten.) Fullaway recommends also plowing a furrow about the field with steep side toward the corn, up which they cannot easily climb. Because mold board plows do not clean well they fail sometimes to leave a vertical "landside" cut, and disc plows never do. However in case of attack, the poisoned bait if placed in such a furrow would be more effective than if thinly scattered.

Aphides are at times well held under control by ladybird beetles, and are quite easily killed by various sprays—proprietary tobacco mixtures being especially recommended.

The leaf hoppers are to some extent checked by egg parasites, but not enough so. Tobacco mixtures—a decoction or as powder may be employed against them. Being well protected beneath the leaf-sheath, however, the result is not entirely satisfactory.

At the Experiment Station the leaf hopper usually destroys all corn after or about the middle of April.

Other insects doing damage at times are the wire worms, attacking the roots; caterpillars eating the leaves; ear worms, infesting the ears; and moths and weevils attacking the mature or stored grain.

If the caterpillars become numerous spray the corn with some compound of arsenic. Fumigation with carbon bisulphide is the best method for controlling insects which attack the stored grain.

DISEASES.

The most common disease of corn is corn smut. It is found in all fields, but usually only one per cent., more or less, of the stalks are attacked. The history of the disease is as follows:

The spores germinate and produce a mold-like growth which bears minute colorless spores. These latter are carried about by the wind and lodge on the corn plant. If they find a moist place, growth is at once started, and the well known black smut soon forms. The history may be completed in three weeks after which it is repeated. The repetition of the process goes on so quickly that the infection spreads rapidly about the field. Much more corn appears to be infected in the later stages of growth. Any fungi remaining undestroyed usually carry the infection over to the following year.

The only practical method of treatment is to gather the smut bodies before they open and discharge their spores—and burn them or dip them in hot water. If this be done a few times at intervals throughout the season the fungus will be kept very well under control.

From the very nature of the fungus it will be readily seen that seed treatment is of no avail. Spraying the plants to prevent growth of the spores could be done, but is impracticable.

Smut is not poisonous to animal life and can be fed with impunity, its feeding value being slightly higher than that of corn. The spores are destroyed when the fungus is eaten.

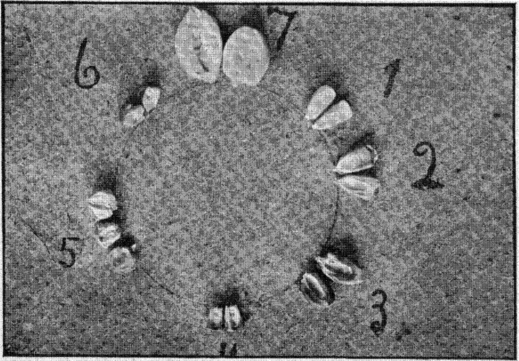

Figure 7. Types of Kernels:

1. Dent corn—long narrow wedge.
2. Dent corn—broad wedge.
3. Dent corn—oval.
4. Dent corn—very short wedge.
5. Sweet corn.
6. Flint corn.
7. Soft corn.

CORN IN HAWAII.

IN KULA, MAUI, corn is usually planted in rows about 5′ apart with hills of three stalks 4′ to 5′ apart in the rows, making about 5800 stalks per acre. Corn here is usually cultivated twice and the yield is from ½ to 1½ "tons" per acre, equivalent to 14 to 43 bushels per acre, depending upon the season. It has been a common practice in Kula to burn all husks and stalks, in preparing the land for the next crop, but in some cases the husks are now being plowed under and, on one or two farms only, stalk cutters are being used. The rainfall in Kula is obtained largely from "Kona" winds the N. E. trades being effectively cut off by the summit of Haleakala. Most of the precipitation therefore occurs in the winter months. The soil is loose and powdery and fall plowing is not necessary to facilitate the percolation of water. Corn is grown year after year and in order to maintain the fertility of the soil some green manure crops should be grown. As suggested in another connection ,small grains, especially wheat, would be found valuable for this purpose, provided of course that there is moisture enough to germinate the seed in the fall when it is sown. In the late winter the soil blows badly and a cover crop, extending over much of the corn belt would in a measure protect the region from the unpleasant dust storms now prevalent. Various legumes should be tried out for a like purpose. As stated also, plowing under of the cover crop must be postponed until the last possible moment which "congests" the spring work.

The variety of corn grown is a yellow dent, which has been more or less mixed with white varieties. As this corn has been grown for many years in this region it will probably be found to be the very best variety for the given conditions. However every effort possible should be made to improve the variety through the use of ear-row tests and breeding plats as explained on page 29.

UPON PARKER RANCH, HAWAII, corn has for some time been one of the principal crops produced. Nearly 2,000 acres are now grown annually. Some is planted near Waimea (2700-4000′) but the larger area is above the frost line at Waikii (4500-5300′). The corn is planted in rows 42″ to 44″ apart. with three kernels in hill and hills 42″ apart, making over 10,000 plants per acre. Frequent shallow cultivations are given to conserve moisture. The soil at Waikii contains, of volatile matter 25.83 per cent, of coarse sand and gravel 1.64 per cent, of fine sand 38.3 per cent, of silt 16.22 per cent, of fine silt 19.99, and of clay 2.05 per cent. It will be noticed that this is a silt loam soil well adapted to corn; the percentage of humus (in the volatile matter) is large, there is an absence of large particles of sand and also of cementing material (clay). The soil then has a great retentive power for moitsure but when dry is very floury and "blows" easily. This soil is rich in lime, magnesia, nitrogen, potash and phosphoric acid. The rainfall here is below 20″ usually, much of which falls during the cooler months. The precipitation in 1912, from April 17th to November 12th was 4.35″ most of which fell in light showers measuring .6″, .5″, to .2″, practically all of which would be valueless for the corn crop, since there was no percolation and all was lost by evaporation. An average yield of 35 bushels per acre was obtained, produced by moisture existing in the soil at planting time and which was conserved by surface cultivation. A small yellow dent corn early maturing, and quite drought resistant is grown here. A lower elevations a larger growing variety of white dent grown.

Upon Molokai Ranch, corn is planted at 800′ elevation rows about 52″ apart. Heretofore single stalks 18″ to 2 apart have been left but the plan is now to extend this interv to 30″, making 4,328 stalks per acre. Under the extreme dry conditions which prevail upon Molokai, a much smal yield of corn than at Waikii is possible.

Upon Oahu a considerable area was for several years pla in corn at Kunia, with varying degrees of success. One a crop of over 40 bushels per acre was obtained, while in years the yield was reduced by attack of caterpillars and hoppers. Near Honolulu, the Experiment Station has the varied success; winter crops succeed best, spring crops d for a time but eventually fail. In Nuuanu valley a m of corn yielded in March, 1913, 37 bushels per acre, t row giving a rate of 60 bus. per acre. The yield forage was at the rate of about 9 tons per acre.

Upon Kauai no extensive areas have been tried in Homestead, judging from the results illustrated in F is possible to produce corn if care is first taken to m land. Doubtless the effect of the manure was as great through the improvement in moisture conditions as in any other way.

CONCLUSION. Corn can be grown, profitably, upon certain areas and under certain conditions, in Hawaii. It is a valuable forage plant, its worth being too well known to need explanation. It is to be one of the mainstays of the stock industry during times of drought, particularly in the form of silage. Seed from island grown corn is to be preferred, but should be carefully selected and improved by breeding. Corn thrives in Hawaii at medium elevations and upon silt loam soils. The corn crop merits more attention than it has in the past received.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU.

E. V. WILCOX, Special Agent in Charge.

PRESS BULLETIN No. 43.

Eye Worm of Chickens

By

E. V. WILCOX.

AND

C. K. McCLELLAND.

INTRODUCTION.

Many of the poultry raisers in and about Honolulu are familiar with the fact of the occurrence of a small, thread-like worm in the eyes of chickens. This worm is known as Manson's eye worm (Oxyspirura mansoni), and, so far as observations have been made, this is a parasite only in the eyes of chickens and peafowls. This worm has been reported as occurring in China, Brazil, Mauritius, Jamaica, Florida, and Hawaii. In all of the localities thus far reported as being infested with the eye worm of chickens the worm is found only near the sea shore, but the wide separation of the countries in which it is found would indicate that probably the worm is generally distributed throughout tropical countries.

The occurrence of species of eye worms in different birds and mammals is rather common. About 38 species of eye worm have been found in the eyes of 43 different species of wild birds throughout the world, and eye worms of other species have also been found in the eye balls or under the eye-lids in horses, cattle, sheep, dogs and geese.

The occurrence of the eye worm of chickens in Honolulu is very general. An examination of chickens in all parts of the town indicate that the worm is found in nearly every flock. In a few flocks of fowls where a start was made by importing fancy eggs from the mainland or by buying eggs of poultry breeders in Honolulu, and starting the business by means of an incubator and brooder, no infestation by eye worm was found. If fowls are brought in from other flocks in Honolulu, however, a more or less extensive infestation is almost sure to be brought about. In cases of slight infestation there may be only two or three worms in each eye, while in badly infested flocks the number of worms may reach 50, 60 or more, in each eye of infested fowls.

ANATOMY OF THE EYE WORM.

The mature worm as found in the eyes of fowls ranges from a little less to a little more than one-half inch in length, and is about the diameter of a fine needle. Numerous measurements of mature worms indicate that the males vary in length from 10 to 14 millimeters, and females from 12 to 18 millimeters. The color of the worms is whitish or semi-transparent. No details of the anatomy of the worm can be seen by the naked eye. Since the average poultry raiser is not provided with a compound microscope and would at any rate have little interest in the microscopic anatomy of the worm it seems unnecessary to go into a discussion of anatomy in this bulletin, particularly since the subject has been so thoroughly covered by Ransom, in Bulletin 60 of the Bureau of Animal Industry of the United States Department of Agriculture.

LOCATION OF THE WORMS IN THE EYE.

Doubtless all poultry raisers are familiar with the gross external anatomy of the eye of fowls, and have observed a third eye lid, commonly called the nictitating or winking membrane, which lies underneath the two eye-lids and moves rapidly back and forth across the eye in a horizontal plane. When the eye is open the nictitating membrane is drawn back into the inner corner of the eye. Fowls and all other birds, wild and domesticated, as well, can therefore wink without moving the outer lids. The eye worms in infested fowls are found in the inner

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corner of the eye, underneath the nictitating membrane. In full grown fowls the worms may therefore not be seen by a casual observation of the eye unless the nictitating membrane is lifted so that a view of the tear sinus or cavity underneath the nictitating membrane is to be had. In an examination of infested fowls in Honolulu as many as 50 or 60 mature worms have been found under the nictitating membrane of a single eye without any of the worms appearing in sight until the nictitating membrane was lifted. In small chicks from ten to twenty days old the sinus under the nictitating membrane is so small that the worms cannot remain concealed in it when the outer eyelids are opened, therefore the worms are seen wriggling over the whole surface of the eye.

METHOD OF EXAMINING THE EYE.

For the rapid examination of the eyes of poultry two persons can work together at better advantage than one alone. With the aid of an assistant, or by holding the fowl securely under the arm and holding the head motionless with one hand, one may press firmly with the thumb-nail over the tear pocket at the inner corner of the eye, and by rubbing gently, but firmly, may succeed in pressing some of the eye worms out upon the surface of the eye-ball, where they may be readily secured. This method of examining, however, is not very satisfactory, and the worms can never be removed completely from the infested eyes without a better system. The mature worms wriggle very actively and immediately disappear under the nictitating membrane after having been pressed out. No amount of manipulation by the method just mentioned will therefore secure a complete removal of the worms from the eye. The constant movement of the nictitating membrane in such manipulation in itself gathers the worms and carries them back into the tear pocket out of sight. If only two or three worms are present in a single eye, this method of examination might fail to discover them at all, and the erroneous conclusion might be reached that no infestation existed.

In the examination of the eyes of chickens, and particularly in any satisfactory treatment of the eye, either for the presence of eye worms or in the case of roup or sore-head, the use of a solution of cocaine has been found necessary as it is to oculists in the examination of the human eye. The extreme sensitiveness of the eye brings about a rapid and continuous movement of the nictitating membrane, which makes it practically impossible to examine the eye thoroughly until it has been desensitized or anaesthetized by the use of cocaine. For this purpose a 5% solution of cocaine in distilled water is used, and may be applied to the eye from an eye dropper or by making a small swab of cotton on a toothpick, rubbing the solution over the surface of the eye. Within a few seconds the chicken makes no further resistance to an examination of the eye. A small swab, made by twisting a bit of cotton about the end of a toothpick, may be used for lifting the nictitating membrane in order to examine the eye and make it possible to drop remedies into the cavity under the nictitating membrane, where the eye worms are found. If the simple swab just mentioned be inserted under the nictitating membrane and pushed forward to the inner corner of the eye and moved upward and out from under the nictitating membrane again, a large proportion of the eye worms may be rubbed out from their hiding place. If two or three such passes with the swab are made without bringing a single worm to view one may be reasonably certain that no infestation of eye worms is present.

The use of a solution of cocaine in examining and treating the eyes of fowls gives us the means of making this examination more thorough and applying remedies with better effect than could possibly be accomplished in other ways. The method was first suggested by Mrs. W. J. Cooper, and has proved very successful in work at this Station. It is not only of use in examining and treating eyes for eye worm, but also in case of roup, sore-head, or any other eye trouble. It is impossible to lift the nictitating membrane and drop any solution into the pocket under the nictitating membrane without the previous use of cocaine; unless, however, the remedy is dropped immediately into the pocket under the nictitating membrane it is of little or no effect, particularly in the treatment of eye worms, for the reason that the presence of whatever remedy is used of sufficient strength to kill eye worms causes an immediate and excessive secretion of tears which dilute the solution of the remedy to such an extent that it is useless, or at least of no avail in killing eye worms. For example, the application even of creolin or zenoleum by dropping it upon the surface of the eye by merely holding the two outer eye-lids apart will never result in destroying the eye worms in the eye, although these substances may be used in 5 or 6% solution. In applying remedies to the eyes of fowls we have observed that tears are formed in such quantity as to run down into the throat in almost a stream. The great quantity of liquid thus formed dilutes whatever remedy is used within a few seconds, so that it is of no further effect. When, however, the solution of creolin or zenoleum, which we have found most effective for the destruction of eye worms, is dropped directly upon the worms underneath the nictitating membrane, they are destroyed almost instantly.

TREATMENT FOR EYE WORM.

Several remedial measures have been suggested by previous investigators of this subject. These suggested remedies include irrigating the eye with a 1 or 2% solution of creolin or chloronaptholeum, a solution of bicarbonate of soda, and removal of the worms by the use of small forceps. As already hinted in the method of examining the eye, the use of forceps or any mechanical method for removing the worms is altogether too tedious and not effective; moreover, at least without the use of cocaine, it is likely to cause more injury to the eye than does the presence of the eye worm. Such weak solutions as 1 or 2% have not been found effective in killing worms in the eye.

In searching for better methods of destroying eye worms a number of remedies have been tried at this Station. Experiments were made first with worms previously removed from the eyes and placed in watch glasses. Under these conditions a 3% solution of zenoleum, a 1% solution of carbolic acid in 50% glycerin, or a one-half per cent solution of bichloride of mercury, would readily kill the worm. These remedies, however, had little effect on these worms in the eye. The contact of the remedy with the eye-lids and eye-ball causes an irritation which results in an excessive secretion of tears, thus almost instantly diluting the remedy used for destroying the worm. At first some hesitation was felt about using stronger solutions of irritant substances directly in the eye, and recourse was had to the use of more or less bland substances such as castor oil, engine oil, kerosene, eucalyptus oil, cottonseed oil, boracic acid solution, certain proprietary eye washes, a 2% solution of permanganate of potash and peroxide of hydrogen. None of these substances was of any value, and the attempt was therefore made to use stronger solutions of creolin and zenoleum after anaesthetizing the eye by the use of a 5% solution of cocaine. When this method of preparing the eye is used and the solutions of creolin and zenoleum are dropped directly upon the worms in the pocket beneath the nictitating membrane a considerable percentage of the worms are destroyed, when either creolin or zenoleum is used in a 4% strength. Some of the worms, however, resist even this strength, and it was often necessary, in order to kill all of the worms in the eye, to use 5% strength of creolin and 6% of zenoleum. As already indicated even these strengths of the remedies in the eye are not effective unless the nictitating membrane is lifted and the solutions are dropped directly upon the worms. The dropping of these remedies in the eye causes a violent wriggling of the worms and a desperate attempt to escape, but they are killed almost immediately. If fowls treated in this way are examined 48 hours afterward no worms will be found in the eye, or occasionally a number of dead ones may be tangled together in a mass which is not easily removed by the motion of the nictitating membrane. The moment the solution of creolin or zenoleum comes in contact with the worms they straighten out and lose the power of holding themselves in the pocket under the nictitating membrane and are washed down through the tear duct into the throat. In one or two instances the dead worms were observed coming into the throat in some quantities together with the creolin solution which had been dropped into the eye. Doubtless any individual dead worms which remain in the eye after treatment and do not fall down through the tear duct into the throat would ultimately be removed by the motion of the nictitating membrane or would be dissolved in the eye fluid.

The treatment just described results in a slight inflammation and soreness of the eye, which persists for perhaps twenty-four hours, which, however, does not prevent the fowls from feeding. Treated fowls during the first twenty-four hours can open their eyes when they wish to feed, but when standing about during the heat of the day keep the eyes closed. Within forty-eight or sixty hours the irritation caused by the remedy passes away entirely, leaving the eye in better condition than it was before treatment, as a result of the irritation caused by the eye worm.

This method of treatment was worked out in a long series of experiments upon adult fowls. In a poultry yard where unusual infestation of eye worms prevailed we had occasion to use the remedy on young chicks two weeks old. The method gave excellent results. In this case the young chicks were dying directly as the result of infestation of eye worms; on account of the small size of the eyes in the young chicks the worms wriggled across the whole surface of the eye-ball constantly, thus causing an irritation and inflammation of the upper and lower lids, nictitating membrane and cornea of the eye. The inflammatory exudation of the eye caused the lids to stick together so that the chickens were totally unable to see and soon died of starvation. In the case of these young chicks the treatment resulted in an apparent complete recovery in twenty-four hours. Similarly with the older fowls in the same poultry yard, some of which had developed a stumbling, staggering gait, from partial blindness or the acute irritation, these fowls also recovered within a few hours, and the owner of the fowls has since treated all of his chickens.

The treatment of eye diseases has always been a bugbear to poultry raisers, on account of the difficulties involved and the tediousness of the operation. Unless the eye is anaesthetized by cocaine the chicken wriggles its head so violently and moves the nictitating membrane so constantly that it is almost impossible to examine or treat the eye thoroughly, but by the method described in this bulletin, a poultryman who had never tried the remedy before found it possible to give thorough treatment to both eyes of sixteen fowls in an hour. The method therefore makes the examination and treatment of the eyes of poultry a practicable operation and one which will not be too tedious for any poultryman.

SYMPTOMS OF EYE WORM INFESTATION.

The symptoms caused by the presence of eye worms under the nictitating membrane in the eyes of chickens varies greatly in different cases. In some instances there may be from 20 to 50 worms in either eye without causing any apparent irritation or inconvenience further than is evidenced by an occasional scratching of the eye on the part of the chicken. The presence of worms in the eyes of chickens, however, is not always an indifferent matter, and sometimes causes death without any other contributing causes, particularly in the case of very young chickens. The worms almost always cause some irritation as evidenced by the behavior of infested fowls. In most cases a certain amount of inflammation can be observed upon the cornea, the eye-lids and particularly in the nictitating membrane, which may become swollen and unusually distended. The excessive secretion of tears is an almost constant symptom of this trouble. In long standing cases the eye liquid may become thickened and purulent, resulting in the closing of the eye-lids and an inflammation of the eye-ball, terminating in its complete destruction. There are many cases of one-eyed chickens in which eye worms were the prime cause of the trouble. Naturally the presence of eye worms is also associated with the occurrence of roup and sore-head, since the irritation caused by the eye worms may give easy lodgement to the organisms which cause roup and sorehead. It often happens, therefore, that it is impossible to say just how much each one of these factors had to do with the ultimate destruction of the eye. In long standing cases where the perulent thickened liquid in the eye finally becomes caseous, no living eye worms can be found, but occasionally a few dead worms will be found embedded in this cheesy mass in the eye. While, therefore, eye worms can hardly be said to cause a specific disease, with uniform symptoms, they do frequently result in the death of the fowls, almost invariably render more easy the infection of fowls with roup and sorehead, and always cause considerable irritation in the eye, which may, as just indicated, result in a destruction of the eye or even in the death of the fowl.

THE LIFE HISTORY OF EYE WORMS.

Previous investigators of this subject have made no contribution to the life history of Manson's eye worm. Until the investigations reported in this bulletin were undertaken nothing was known of where the eggs were hatched, how and where the young worms pass their life, nor how, nor in what stage the worms gain entrance to the eyes of previously uninfested fowls. Since, therefore, the life history of the worms was totally unknown it was thought very desirable to make an effort to determine this in part. While the method described proved quite efficient in destroying the worms in the eye it still seemed desirable to gain some idea of the life history of the worms in order to apply any additional method of control which might be suggested by the knowledge of the life history of the parasitic worm. An attempt was made to reach some definite information about the life history of the worm by a study of the various possible methods by which the worm might be transmitted from one fowl to another.

It had been suggested that the eye worm might possibly live for a portion of its life in the blood of infested fowls, or might be carried by the biting of insects. An examination was therefore made of the blood of numerous fowls infested with eye worms. No stages of the eye worm were found in this series of blood examinations. The only filarial parasite found in the blood was Microfilaria seguini. This organism had previously been found by Mathis and Leger, and Ransom, and has nothing to do with the life stages of the eye worm.

Infested fowls were thoroughly treated, so as to destroy all worms in the eyes, and were then confined in a mosquito proof house, on dry board floor, for two and one-half months. At the end of that time no worms were found in their eyes, and since no microscopic forms could be found in the blood, and none appeared in the eyes after the original infestation had been destroyed it was considered useless to make further experiments on the hypothesis that the worms were carried from fowl to fowl by any biting insect. An interesting fact observed by a number of previous investigators is that no eggs or larval forms of the eye worm can ever be found in the eye of infested fowls, no matter how badly infested they may be. We have made numerous careful examinations of the eye liquid from infested fowls and have never discovered a single egg or larval form of the worm in this liquid, although the eye may contain numerous mature female worms completely filled with eggs. It was at once suspected, however, since the eggs and larval forms are much smaller in diameter than the diameter of the tear duct that they would be promptly washed down through the tear duct by the flow of tears caused by the irritation of the eye from the eye worm. We therefore began to examine the feces of infested fowls and found large numbers of eggs at once; in fact the minutest granule of feces suitable for one cover glass preparation under the microscope contains from 2 to 5 eggs. In all of the examinations which we made on the samples of feces we found but one freshly hatched larva. It appeared, therefore, that the eggs must hatch after passing out of the body along with the feces. The numerous eggs which we found in the feces and the one young larva were carefully identified by comparison with eggs from mature female worms and from larvae obtained by hatching such eggs in 1/10 normal salt solution. It was evident that these were washed through the tear duct by the eye liquid, issuing in the throat and then being swallowed, and then passing out with the feces. As already indicated we observed this process in the case of mature worms which could be readily seen with the naked eye. Of course the eggs and newly hatched larvae being only about .2 of a millimeter in size cannot be seen by the unaided eye. It is possible that the cases which we have observed of the natural disappearance of the worm from the eye may be taken as indicating that at complete maturity some of the female worms pass down through the tear duct and are disintegrated in passing through the intestines, thus setting free the numerous eggs which they contained.

A number of breeding experiments were then started by placing feces from infested fowls upon moist earth. In the first experiments we used ordinary bare soil, fresh from the garden, and in other experiments thoroughly sterilized soil. It was found that the growth of the young larvae was much more rapid in sterilized soil. Within there weeks in the case of unsterilized soil it is possible to find numerous young larvae about .2 millimeter in length. They were active and showed a number of methods of locomotion; in about ten days they were from .3 to .43 millimeter; after a period of three months a number of forms .5 millimeter were found. In the sterilized soil upon which the feces from infested fowls was placed numerous larvae were found within twelve days ranging in length from .2 to .8 millimeter. The soil was kept moist, or practically saturated, with sterilized water. One unhatched egg was found in the soil just underneath the feces even after 23 days, but at that time nearly all of the larvae ranged in length from .4 to .66 millimeter. After a period of four months a number of larvae from .85 to nearly 1 millimeter were found in the sterilized soil. The live worms in this soil were so numerous that when a small particle of soil was placed in a watch glass to which a bit of distilled water was added, one drop of solution taken up in a pipette and placed on a microscopic slide would contain from 2 to 10 larvae.

Since the growth of the young worm in moist soil seemed to be so slow it was thought desirable to examine the soil about badly infested poultry yards. Opportunity was had to get soil of this sort in the case of an unusually severe infestation of eye worms in a poultry yard in Honolulu. In this case the fowls were allowed to run about the lawn, which was well grassed over except for small circular areas about the base of certain fruit trees. On these small areas of soil the fowls rested during the heat of the day, digging, dusting themselves, and such soil was badly contaminated with feces. This soil was kept moist by the application of water to the trees. In these circular areas about the trees samples of soil were taken, which revealed under the microscope untold numbers of larvae of the eye worm, as many as 20 being found in a single cover glass preparation. In the soil underneath the roosts in the simple poultry house in the case in question no larvae were found, but this is obviously to be explained by the fact that the soil was dry and kept constantly dusted with quick lime.

The young larvae of the eye worm in the soil are quite readily distinguished from the free living nematodes, which are abundant about the roots of various plants in tropical countries, by the facts that the eye worm larvae have no spear or projecting mouth parts and no striation upon the cuticle. By the time the larvae reach the length of about 1 millimeter the anatomical differences between the sexes begin to appear; the tail of the male is bent ventrally, as in the case of the adult, and the beginning of the spicula is seen.

It would appear, therefore, that the eye worm of chickens is essentially a facultative parasite, capable of living a large part of its life, probably to maturity, in damp soil, and then gaining entrance to the eye of fowls, where it lives as a true parasite. Similar conditions have been observed by Ercolani who carried a number of parasitic nematodes through several generations in damp soil. The species with which Ercolani worked were Strongylus filaria, S. armatus, Arcaris inflexa, A. vesicularis, and Oxyuris curvata. The longest larva which we have thus far obtained from damp soil was about 1 millimeter, and the shortest immature worm which we have ever been able to find in the eye of chickens was about 4 millimeters. The cycle of the life history of the eye worm is therefore not quite completed, and the absolute proof that the worm gains its entrance to the eyes of fowls directly from the soil has not been brought forward the circumstancial evidence which we have produced, however, is so strong that it seems impossible to assume any other method of transmission. In the first place it is beyond question that the worms do not reproduce or multiply in the eye, only a portion of the life of one generation is passed in the eye. The eggs are immediately washed out of the eye into the tear duct and hatched in the soil after passing out of the body with the feces. Repeated experiments by other investigators and here at the Station have shown that fowls do not become infested when fed with material containing innumerable larvae of the eye worm. They cannot therefore disengage themselves from the food and pass up through the tear duct into the eye, nor have they the ability to reach the eye by passing through tissues, or otherwise, from the alimentary tract. We have also fed uninfested fowls with mature eye worms without producing any infestation. Similarly an infestation of the eye cannot be brought about by feeding eggs of the eye worm. We have tried placing the mature eggs and young larvae in the eyes of uninfested fowls without producing infestation; they were simply washed down the tear duct, as would have happened had eggs been laid by mature worms in the eye. It appears to be impossible for an eye worm to maintain a hold and keep its position in the eye until it has reached a size of at least 3 or 4 millimeters.

We found, however, that when mature or nearly mature worms are placed on the outside of the outer eye-lids they almost instantly wriggle into the eye. It seems, therefore, to be practically proved by circumstantial and other direct evidence that the eye worm gains entrance to uninfested fowls directly from the soil into the eye in the process of dusting and rolling about in the soil, and in picking and scratching. The frequency with which fowls scratch the side of the head with the foot covered with soil in which they are digging has often been noticed, and the opportunity for the infestation of the eye, where the soil contains thousands upon thousands of eye worms, is exceedingly good. It is certain also that the worm gains entrance to the eye only after it has become nearly or entirely mature. The final evidence for this was obtained by finding a bad infestation with mature eye worms in chickens 10 days old. It was, of course, impossible in this case that any great amount of growth in the worms should have taken place after they gained entrance to the eye.

When infested fowls are kept in a cage with dry board floors, together with uninfested fowls no spread of the eye worm takes place so long as the boards are kept dry and the feces frequently removed. We have carried on the experiments with such direct exposure for five months without producing any infestation. When fully mature worms are removed from the eye of one fowl and placed in that of another they do not always remain more than a week or ten days. This apparently indicates that their life functions were at an end and they simply passed down through the tear duct. In one or two cases of bad infestation the worms completely disappeared from the eyes of infested fowls which were kept confined in a cage on dry boards. It is apparent, therefore, that so long as no opportunity from reinfestation is offered from infested soil a single infestation has a limited course and ends when the worms have reached complete maturity and disappear down the tear duct.

SUMMARY.

It appears from the investigations reported in this bulletin that the eggs of the eye worm of chickens are either laid in the eye, from which they are immediately washed into the throat by the flow of tears down the tear duct, or are set free in the intestines by the disintegration of mature female worms which had passed down the tear duct, through the throat, into the intestines.. The eggs hatch for the most part or altogether in damp soil, where they live until they attain at least one-third of their mature size, and then gain entrance to the eyes of chickens directly from the soil. The best treatment for the destruction of the eye worms in the eyes of fowls consists in anaesthetizing the eye with a 5% solution of cocaine and then lifting the nictitating membrane and dropping a 5% solution of creolin directly into the inner corner of the eye, under the nictitating membrane. The fact that soil contaminated with the feces of infested fowls contains thousands of the larvae of the eye worm makes it obvious that means should be taken to destroy the young worms in such situations. This may be accomplished by applying quick lime and keeping the soil as dry as possible, and also by the frequent cleaning and removal of all feces from infested yards, or, in the case of bad infestations, by keeping the birds on dry floors which can be frequently cleaned until the infestation has disappeared.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU.

E. V. WILCOX, SPECIAL AGENT IN CHARGE.

PRESS BULLETIN No. 44.

PLANTATION RUBBER IN HAWAII

BY

W. A. ANDERSON.

INTRODUCTION.

The rubber industry in Hawaii finds itself under a disadvantage as regards the cost of labor as compared with rubber plantations in other countries. The price of labor may be reduced in Hawaii, while wages in most of the rubber plantation countries are increasing. How far this movement will go no one can say. It is safe to predict, however, that the price of free labor in Hawaii will not for many years reach the level of the wages paid to the contract labor of the far East. To be sure, the cost of supervision, and general "overhead charges" are rather less in Hawaii. There still remains, however, a consirerable balance in favor of the Eastern plantations.

To minimize this difference will require constant effort toward better methods and closer economies. Fortunately, the rubber industry is in its infancy the world over, and holds possibilities of important discoveries in methods of tapping, and even, possibly, of cultivation. In Bulletins Nos. 16 and 19, and Press Bulletin No. 13, of this Station, are given the results of various experiments in tapping, and general observations on the industry in Hawaii up to the time of their publication. The aim of this Bulletin is to give a summary of the observations made since their publication.

PLANTING.

The plantations were naturally all started with seedlings. Cuttings will probably henceforth be the best method of propagation. The cuttings planted in 1907 have grown as well as seedlings under the same conditions, and yielded as well. Planting with cuttings permits selection from the best yielding trees. One acre was planted in 1911 in this way. These will be tappable by the end of the next tapping season, when they will be two years old. It will then be possible to determine whether or not they partake of the high yielding properties of the parents. If they do, this will prove unquestionably the best method of extending the plantations, as the well known variation in yielding capacity of different trees will in this way be largely eliminated, and a plantation developed on which all the trees are good yielders.

While 100 trees per acre would appear to be approximately the proper number for a permanent stand, there are distinct advantages in planting closely and subsequently thinning out by removing the poor growers and poor yielders. Among these advantages are:

A. The ground is more quickly covered by foliage, making weeding expense less, and reducing erosion.

B. The trees protect each other to a greater extent from damage by heavy winds.

C. Close planting allows thinning out by selection. This is, perhaps, the chief advantage. Thinning out can be done as the trees begin to crowd each other, by first removing the poorest growers, then, the trees which have been found to yield poorly. As the trees are not true to seed as regards yielding properties, this would seem to be the only effective method of selecting the best individuals, so long as planting is done with seedlings. In the case of selected cuttings, naturally, this is of less importance.

D. With the trees closely planted better results are obtained from early tappings. Until they begin to crowd each other to such an extent as to affect the flow of latex, it is obvious that more rubber will be obtained from 400 trees per acre than from 100. This, of course, holds equally true in the case of cuttings. So long as the yield per tree is not affected, the more trees per acre the more rubber per acre. This principle appears to be gaining ground in the eastern plantations, and less is heard than formerly of the discussion as to close vs. wide planting[1], although opinions as to the proper distance for the permanent stand have not greatly altered.

The disadvantages urged against close planting are:

A. The trees are apt to be left too long before thinning, so that a permanent set-back is given them. This objection is not necessary to the system, but depends on the planter.

B. Thinning out by selection leaves the trees more unevenly spaced than if originally planted 20x20. This irregularity will permanently increase the cost of tapping per acre.

The amount of this increase will depend on the method of working. For instance, if the trees are evenly spaced, 20x20, there are 108 trees per acre, equivalent to 9 rows of 12 trees

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[1] See Tropical Agriculturist, Jan. 1913.

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shifting at the ends of the rows ,making a total distance traveled of 2160 plus 180, or 2340 feet, in tapping one acre. If the acre contains the same number of trees, thinned by selection from planting 10 by 10, there will be 18 rows containing an irregular number of trees but averaging 6 trees per row. In tapping by rows, the man must travel 240 feet for each of the 18 rows, and the same distance as before in shifting, making a total of 4320 plus 180, or 4500 feet, in tapping the acre. The difference is 2160 feet additional distance traveled in tapping the irregular trees—nearly twice as far, and, roughly speaking, one mile for each two and one quarter acres tapped. In tapping a thousand trees, he will cover 9 acres, traveling an additional distance of 4 miles.

This difference can be materially reduced by tapping two rows at a time in the second instance instead of one. In this way, the additional distance traveled for each two lines will be reduced to about five feet for each tree in the second line. If this second line contains only two trees, for instance, it will be necessary to travel only ten feet farther in tapping these two lines than in tapping one. If this were the average content of second lines, then, the additional distance traveled for the acre would be only 90 feet or 810 feet for each thousand trees. The maximum possible content for the second lines is six trees, hence the miximum possible difference in travel will be 30 feet for each two lines, 270 feet per acre and 2430 feet per thousand trees—less than ⅛ that caused by the single row system. This applies of couse, only to cases where the trees are irregularly placed, or where the distance between each two rows is less than the average distance between each two trees in the rows. It therefore does not apply to either the 10 by 10 planting before thinning, or 20 by 20 planting.

It does, however, reduce the necessary additional cost of tapping per acre caused by irregular spacing, to a point where, as compared with the advantages of close planting pointed out above, it is negligible.

C. Cost of thinning out. The cost of cutting down and removing trees of the size these will be, if removed at the proper time, is more than offset by the gain made through the selection of the best ¼ of the trees.

D. The danger of fostering diseases and pests by the dead stumps left in the field in thinning out. This is, so far, a theoretical objection. In some of the Eastern Hevea plantations, where the policy has been pursued for several years, no evidence has been discovered of injury from this source. (See summary of paper by Mr. C. E. S. Baxendale in the Tropical Agriculturist for Jan. 1913.) It can be guarded against, if considered necessary, at some additional expense, by removing each. Tapping these, one row at a time, the tapper walks 240 feet for each of nine rows, and 20 times 9, or 180 feet in the stumps, which at this age are not large. So far, in the Nahiku district, the stumps have been left in the ground.

On the whole, the practise of planting the trees ten by ten and thinning out by selection to the desired number per acre is justified by results. Its chief advantages are the increased yield per acre during the first tappings, and the opportunity it gives of thinning out the poorer trees, leaving only the best. Most of the fields have been thinned somewhat, but comparatively few acres have been reduced to 108 trees per acre. This will probably not be completed before the trees are 8 or 9 years old.

CULTIVATION.

The question of cultivation is one of providing for the proper nourishment. The three main factors are weeding, fertilizing, and aeration. According to present theories there are two classes of noxious weeds; those which are positively injurious through their toxic effects, and those whose injuriousness is confined to the removal of necessary nourishment from the soil. Some plants may cause injury from both these causes. Besides these there are the beneficial weeds, as the legumes. It is also conceded that these beneficial plants may be grown under such conditions as to become injurious; as with legumes, while adding nitrogen, they might, especially the shrubby sorts, under certain conditions, remove too much potash or phosphoric acid.

Most of the work in Nahiku has been directed toward extermination of injurious weeds. Some attempts have been made to replace the injurious weeds with legumes, but for this to be done to the best advantage, it should be done at the time of planting the trees, and soon after clearing, before other growth has obtained a footing. Cutting the grass and mulching is recommended by some authorities for orchards in hilly country (Ohio Exp. Sta. Bulletin No. 240). This was done at Nahiku for about four years. A cheaper and apparently as effective method was found in the arsenite of soda spray, which is the subject of another bulletin of this Station. (Press Bulletin No. 30.) One purpose of the mulch, the conservation of moisture, is not needed in Nahiku. The spray is in general use on all the plantations. In Nahiku, the abundant and frequent rains, with numerous gulches, in which water can be found convenient at all seasons of the year, make it especially adapted. It allows the air to get to the soil rather better than the cutting and mulching, as the dried grass stems are left standing for some weeks after application and when they do fall over it is a gradual bending down, and the base of the stems still hold the mulch slightly off the soil until decay is somewhat advanced.

Arsenite of soda should not be allowed to touch the foliage of any trees or the stems of Ceara trees under two years of age, or of Hevea trees at all. In the case of Ceara trees over two years of age, the tough outer bark furnishes protection from injury. If allowed to touch them where this bark has been recently removed for tapping, however, all the inner bark is burnt off to the wood. Properly handled, it is the cheapest effective method of weeding yet found. Horse cultivation, where it is possible, on the more level lands gives good results, but this can not be employed on all the lands without excessive loss from erosion. Hoeing the entire surface, the common practice in the far east, is impracticable for two reasons, the loss by erosion, and the enormous expense.

INTERPLANTING.

A great deal has been written and considerable work done on the subject of keeping down obnoxious weeds fostering the growth of those less obnoxious or of beneficial plants. Passion vines, peanuts, Crotalaria and other legumes, have been used. With all, the main idea was the choking or shading out of undesirable growth. So far, we have not found this profitable. It is possible that this was because our experiments were made after the Hilo grass and other troublesome weeds had become established. It was then necessary, in order to get the beneficial plants established, to keep hoeing out the undesired growth. It was found more expensive to establish and maintain the legumes than to keep the grasses down with the spray. It is possible that the advantages gained through the addition of nitrogen by the legumes might offset this additional cost, but this is doubtful.

A better practice, where horse cultivation can be employed, is the planting of intercrops, which are valuable for themselves, aside from weed checking. The additional cost of the cultivation can be more than recovered from field corn, Irish potatoes, broom corn, and probably from others. Sweet potatoes have been found to grow well and yield heavily on the lower lands. If a profitable local use can be found for these, they should be a good crop for the purpose, as the vines furnish a complete cover to the soil for several months, and, after harvesting, supply a good quantity of manure. Field corn does rather better on the high lands. Broom corn grows excellently, and yielded three crops from one planting. The bulkiness of the crop in comparison with its value, however, makes it undesirable where transportation facilities are at all difficult. In general, it may be said that any crop that can be grown profitably in the district can be used as an intercrop. Naturally, other things being equal, the crop will be selected which will take the least nourishment from the trees. In soils rich in humus, as most of the Nahiku soils are, it would seem that no serious impoverishment of the soil should result from the raising of two or even three, crops of any suitable sort.

FERTILIZING.

Much work remains to be done on this subject. Some soil analyses made by Mr. Kelley of this station, showed a large amount of humus, and generally speaking a sufficient amount of the chief food essentials. He points out, however, that the occurrence of the iron in the ferrous state indicates the need of aeration. An experiment was made in 1909 to determine if possible the effect of ammonium sulfate, superphosphate and potassium sulfate, alone, and in combination. Results in growth as compared with the check trees that were given the same cultivation without fertilizer, were not marked, and, while this experiment is not considered conclusive, it would seem to indicate that, considering the additional cost of the fertilizer, possibly, for some time, at least, aeration and cultivation without the addition of fertilizers should give as satisfactory results.

An important subject of investigation, and one which has not as yet been undertaken on a large scale, is the effect of fertilizing on the yield of latex. Some experiments were made by this station in 1909, the results of which are reported in Bulletin No. 19. It is hoped that during the present year, these may be supplemented by a carefully planned and executed experiment on a field scale, on a large enough number of trees to make individual variation in yielding properties negligible, and continued from the beginning of the growing season to the end of the tapping season.

AERATION.

The availability of plant foods in the soil depends on a sufficient supply of oxygen. Most of the soils on the upper lands in the Nahiku Rubber district are rather finely divided, and either saturated with moisture to the exclusion of air or reduced by erosion and packing to impenetrability to either air or moisture. In some places ditches have helped to promote circulation, but something further is needed to provide thorough aeration. Horse cultivation gave quick and noticeable results where it could be employed. This, however, stirs up the top soil for only a few inches, and much of the benefit is counteracted by the loss of the best top soil from erosion.

In April of this year an experiment was made with dynamite in the hope that this, in connection with weed eradication by arsenite of soda, might furnish a fairly complete method of cultivation in this district, where the combination of steep slopes and heavy rains and finely divided soil, covered with trees having large surface roots, makes other methods of cultivation difficult and expensive. It is too early yet to note the effect on the trees, but the experience of others where dynamite has been used in orchards, leaves the question only one of the amount of benefit received. As the benefits of this sort of cultivation have been found to last for 10 to 20 years on the mainland, the cost of fifteen to twenty dollars per acre, would seem to be small as compared with the benefit to be expected. In damp soil the dynamite shows a tendency to make a balloon-shaped hole, and the shattering effects extends over a smaller area. The holes formed, however, are as a rule filled with well-loosened soil, providing good opportunity for aeration.

TAPPING.

The tapping difficulties peculiar to the Ceara tree are due to the character of the outer bark and the thinness of the inner bark, containing the latex cells. For any system of tapping by excision the thinness of the inner bark offers the chief objection. It is impossible to make a channel that will extract the maximum amount of latex and conduct it to the cup without frequently reaching the cambium. At the same time, the nature of the outer bark offers serious obstances to tapping by incision. If this bark is not removed before incision, much of the latex is lost between the outer and inner barks. The following mothods have been tried on the trees at Nahiku:

1. Paring and collecting in cups at the base of the tree. Vertical cuts, single V, multiple V, half herring bone and full herring bone were all employed. The tendency to either injure the cambium or fail to get the full yield of latex applies equally, which-ever system of cuts is employed.

2. Paring and pricking, and collecting in cups. To avoid injury to the cambium, the excisions were made more shallow and followed by pricking to get the latex near the cambium. This gave better results than 1, but it was found difficult to conduct the latex in the shallow channels.

3. Removal of the entire outer bark and pricking vertically with a wheel pricker, collecting in cups at the base of the tree. This gave good yields immediately after the removal of the bark, but the injury caused by bark removal and the rapid formation of a new outer bark, preventing a long series of tappings, after one stripping with the cost of repeated bark removal, are serious objections.

4. Removal of the outer bark in horizontal sections, painting with acetic acid to coagulate the latex, and pricking or jabbing. This method is advocated by Wicherly. The cost of applying acetic acid and collecting the rubber coagulated on the trees was too high.

5. No. 4 was modified and simplified by allowing the latex to flow to the ground and coagulate there. This worked very well for the first horizontal section and the first stripping, but on higher sections too much latex was coagulated on the tree, and the stripping of renewed bark was expensive.

6. Removal of the outer bark on a one foot horizontal section, followed by a vertical incision with a knife-blade the full length of the section, allowing the latex to coagulate on the ground. This gave good results until the first section had been exhausted, but could not be continued higher up on the tree, and subsequent removal of the renewed outer bark at the base of the tree was very expensive.

It became evident, during the progress of these experiments, (a) that a good grade or rubber could be obtained more cheaply by allowing the latex to coagulate on the ground and washing carefully, than by using cups and spouts; (b) that a good yield could be obtained from a knife-blade incision after removal of the outer bark; (c) that the outer bark should be removed in sections and not all at one time. Therefore, a knife was needed which would remove this outer bark on the section desired at one operation. It is the renewed bark which gives the chief trouble. A knife was finally made which would remove the outer bark in strips of any desired width, leaving the inner bark exposed for incision. In August, 1912, tapping was commenced by the following method: The outer bark is removed in a vertical strip, ¾-inch wide from the ground to a height of about 6 feet. The following day the inner bark is jabbed with a thin blade 1-inch wide, as light in weight as consistent with the necessary rigidity. The incisions are made diagonally sloping upward from the left, at an angle of about 45 degrees and about 4-inches apart. The latex flows to the lower end of each incision, and then down the smooth inner bark to the next incision below, follows along to the lower end of this, then down to the next, and so on, till it reaches the base of the tree in a single stream. This is repeated on each of the next two days, making three tappings by incision, in three days. On the day following the last tapping, the coagulated rubber is collected and taken to the washing machine.

The process is thus divided into three operations; removing the outer bark, (excision), jabbing the inner bark (incision), and collecting. The best men are selected for the removal of the outer bark. After a few weeks of experience this operation was performed at the rate of 1200 trees per day's work. The jabbing can be done at about the same rate. Collecting is at the rate of about 12 to 15 lbs. per day's work.

During the eight months, August, 1912 to April, 1913, on one field of trees averaging 6 years old, it took 710 days' work to tap and collect 2193 lbs. washed rubber. During the same time these trees produced 440 lbs. of rubber that coagulated on the trees, and was collected as scrap. Thus, roughly speaking, the yield may be estimated at three pounds per day's work, and 20% of the latex coagulates on the tree.

As mentioned above, it is difficult to tap the Ceara tree by excision, without too frequently injuring the cambium. At the same time, the character of the outer bark makes its removal desirable before incision. In the method just outlined, the aim is to remove only the outer bark by excision. There is no effort to obtain latex at this operation. It does happen, however, that the knife sometimes enters the inner bark. The effect of this instead of causing injury, is simply to start a flow of latex. There is little danger of injuring the cambium in removing the bark. The chief danger lies in the careless use of the jabbers. A quick, light incision causes no apparent injury. If the cut is made with too much force, however, or the blade, instead of being directly withdrawn, is allowed to turn or scrape in the cut, a wound is made which causes a permanent lump in the wood. The chances of this are greater in the case of small trees or trees whose bark is thin. It is possible that a wheel pricker can be evolved which will do away with this objection.

The method of collecting directly from the soil without cups has been practised widely in other Ceara growing countries. It is hoped, however, that a container will eventually be found which can be used in such a way as to facilitate collecting. A circular trough of cement and sand is now under trial at the Sub-Station.

As a receptacle it is quite satisfactory, when properly made, and allows tapping on the lowest portion of the trunk, which is essential to the best yield. Its economy will depend on the length of time the trough will last without repairs. Some that have been on the trees for four months are still in good condition.

The proportion of rubber that remains on the trees to be collected in the form of scrap varies according to the weather. During dry weather, as much as 30% has been collected as scrap, while in ordinary weather, with daily rains, the amount is much smaller, and during November of last year, it was so small as to be not worth collecting. While the so-called "scrap rubber" collected in this way, by washing, can be made as valuable as that collected at the base of the trees, it costs more to collect, and consequently, the greater the amount of scrap, the more expensive the tapping is as a whole.

During August and September the tapping was rather light, but through October, November and December of 1912, and January, February, March and nearly through April of 1913 the trees were tapped on an average of four times in seven days, or 16 times a month. As previously ascertained, the yield is less during hot dry weather, and the amount of scrap is greater. In cloudy and rainy weather, such as occurs usually in October, November and December, and in February and March, and often in April, the tapping can be carried on well into the afternoon, while in dry weather it must be done in the morning. It was found good practice to plan the work so as to have the jabbing, from which the latex is mostly obtained, done in the morning, and to use the labor for collecting and other work during the remainder of the day. The conclusion as to the proper season for tapping is that good yields can be obtained from September to April, in ordinary seasons.

CURING.

A good rubber is one free from mechanical impurities, of high tensile strength, high elasticity, and low resin content. The standard with which all rubber is compared, is Upriver Fine Para. Until within the last two years, this rubber received the highest prices in the market. Of late, however, the sorts generally known to the trade as "Ceylon Plantation", by which is meant all the Far Eastern Plantation Para (Hevea) rubber of the best quality, have been quoted higher than Fine Para. Ceylon Plantation rubber contains practically no mechanical impurities, while Upriver Fine may contain as high as 15% or even 20%. Generally, however, the purchaser of Para is protected against a loss of more than a certain per cent. Ceara, or Manihot, rubber contains more resin than Para, and is generally of lower tensile strength.

With the method of collecting described above, it is naturally more difficult to free the rubber from dirt than if it were collected in cups and kept clean throughout its manipulation. This is done by washing with corrugated rollers, which leave it in the form of coarse crepe.

Resin content is generally understood to be affected by the variety and age of the tree, and to have very little connection with the method of curing, though there is some slight indication that it may be affected by the character of the weather during which the trees are tapped. If this is true, it would naturally follow that it would be affected in the same way by the general climate in which the trees are grown. The data on this, however, are not sufficient at this time to warrant a definite conclusion. The indications are that hot, dry weather may increase the resin content. The establishment of this theory is a matter for further investigation.

Tensile strength and elasticity are affected by the method of curing. Our experience indicates that the method of drying has more to do with this than the method of washing. Rubber dried in the air, with no attention paid to light or temperature, was graded over 20% below rubber treated in every other respect the same, so far as our records could determine, but dried in the vacuum dryer at a temperature below 120° F. That this was due in large measure to the difference in temperature which was established by drying one sample in the vacuum dryer with the door left open, so that no vacuum was created. Under these conditions, the temperature alone was responsible for the noticeable increase in tensile strength and stretch which took place during three hours. As the Station is not equipped with apparatus for making accurate strength tests, either absolute or comparative, only rather marked differences can be noted at the present time.

The practice during most of the 1912-13 crop on the plantations was to dry in the atmosphere for two weeks or more and then finish the process in the vacuum dryer. The manufacturer's tests on rubber cured in this way given below, show a fairly uniform product, graded by them at 5 to 10% below Ceylon Plantation.

Below are the results of the seven analyses made since the adoption of this method of drying:

Date.	Loss in Washing	Strength	Elasticity	Resin.
July 16, 1912....	½%	1710	15¼"	3.98%
July 16, 1912....	⅔%	1660	15 "	4 %
July 16, 1912....	1 %	1660	15 "	2.12%
July 19, 1912....	**	1640	14¾"	2.91
Oct. 23, 1912....	2½%	1620	13⅜	5.09
Mar. 13, 1913....	2½%	1720	13⅜	2.90
Mar. 13, 1913....	1⅓	1740	13⅜	3.27
AVERAGE	1.21%	1675	14¼	3.47%

** Very slight.

As the loss in washing and drying includes moixture as well as other foreign matter, it is plain that notwithstanding the large amount of dirt collected with the rubber, it is possible to remove this with the equipment now on the plantations.

It is probable that quite as good a product could be obtained with a properly equipped drying room, with artificial heat. The comparative economy of the drying room and vacuum dryer would constitute the determining factor in the final choice.

It is hoped that during the coming year the Substation may be equipped to make comparative strength tests at once, when it will be possible to determine the comparative value of the two methods of drying.

There is a possibility that the additional washing required to remove the large amount of dirt due to the method of collecting may weaken the rubber somewhat. At present we have not been able to determine this.

The rubber from which the analysis of October 23 was made was collected during the summer months, when the weather was warmer and dryer than during the winter. The high resin content of this sample lends color to the theory that the weather or climate has some effect on the quality in this respect.

We are indebted to The Manhattan Rubber Manufacturing

Company for the above analyses. In reporting on various samples tested by them they have remarked: "Nahiku Rubber is almost as good as Ceylon, except that there is some loss in washing." The above rubber compares favorably with Ceylon, being about 5 to 10% poorer in quality." "About 10% poorer than Ceylon, as loss in washing is about 2 1-5%" etc. With regard to the rubber cured in light, and in ordinary temperature, their comment was that it "could best be classed with guayule."

From this it may be concluded that, tapped and collected as above described, and dried in the vacuum dryer, our plantations can turn out a product about 5 to 10% below Ceylon plantation rubber in quality. Even if it were possible to make our Ceara rubber equal to the Ceylon Para, of which there is some doubt, by keeping the latex clean with the use of cups and spouts, the additional expense would more than offset the difference. It is possible also that with better facilities and greater experience we may be able to overcome some of the difference that now exists.

It was found that if the temperature of the heating water in the vacuum dryer is allowed to go above 120° F the rubber becomes soft and sticky in spots.

SUMMARY.

The general conclusions with regard to the plantations at Nahiku are:

a. That it is better to plant closely and later thin out to about 20 by 20 in the case of seedliings than to plant 20 by 20.

b. That propagation by selecting cuttings from the best yielding trees is the best means of extending the plantations.

c. The cheapest effective method of weed eradication is by the use of arsenite of soda, and indications are that aeration can be obtained without excessive erosion by using dynamite.

d. The best method of tapping so far is by removing the outer bark in narrow vertical strips and tapping these strips by incision, allowing the latex to coagulate on the ground.

e. Drying in the air at ordinary temperature has not given a uniformly good product, but a uniform product of high quality is obtained by drying for two weeks or more in the air at ordinary temperature and finishing in the vacuum dryer at artificial temperature not greater than 120° F.

f. The product of the Hawaiian plantations can be depended upon to bring a price within 5 to 10% of that of Ceylon plantation rubber.

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Hawaii Agricultural Experiment Station

HONOLULU

E. V. WILCOX, Special Agent in Charge

PRESS BULLETIN 45

An Experiment in Marketing Under Territorial Auspices

By E. V. Wilcox

and

A. T. Longley

ORGANIZATION OF THE MARKET

By E. V. Wilcox

Introduction.

The natural risks and difficulties in diversified agriculture in Hawaii are probably not greater than on the mainland. Hawaiian farming communities are small, however, and the farmers are somewhat isolated by differences of race and customs and by lack of marketing facilities. Recognizing the many artificial difficulties hindering the success of the farmer, the Territorial Legislature by joint resolution of the session of 1909 appointed a fruit growing and truck farming commission, with the special agent in charge of this Station as chairman. The commission made a careful study of marketing conditions in Honolulu and elsewhere in the Territory, and submitted a report on the subject in February, 1910. The report contained the recommendation that the Territory assist in organizing better marketing conditions for local produce. It was originally intended that the work be done under the supervision of this Station.

The attorney general ruled, however, that the Territorial funds at the disposal of the Station could not be used for that purpose. The Territorial market was therefore maintained for nearly two years under the Department of Immigration, Labor and Statistics.

At the 1913 session of the Territorial legislature an act was passed specifically providing funds for this Station, to be used in furthering the production and marketing of miscellaneous agricultural crops of a promising nature which had up to that time not been established on a paying basis. The allotment of $30,000 provided for the biennial period was left to the discretion of the Station. It was suggested, however, that sufficient funds be used specifically for marketing work to put upon a business basis the marketing of miscellaneous home-grown products in Honolulu. The act did not provide for the transfer of any of the property which had accumulated and been used by the Department of Immigration, Labor and Statistics for marketing. Neither did it make accessible to the Station any of the correspondence relating to the work which had previously been done along the line of marketing. It was necessary at the start, therefore, for the Station to learn on its own initiative, the names and addresses of farmers who might wish to take advantage of a public market for their products, and to make known to the buying public the fact of the existence of such a market.

THE TERRITORIAL MARKETING DIVISION.

The U. S. Experiment Station established a Territorial Marketing Division under its supervision July 1, 1913. The work has been carried on for 10 months. The Division has received and marketed farm produce as follows: July, 1913, $303.41, August $125.56, September $262.11, October $84.05, November $802.53, December $1512.82, January 1914, $1820.82, February $2171.61, March $4003.68, April $5509.42, or a total of $16,595.87 for the 10 months. The total expense for this work has amounted to $1490.99, or about 9 per cent of the value of produce marketed.

The consignments sent to the Division have included pigs,

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turkeys, chickens, ducks, eggs, butter, beef, corn, beans, peas, sweet potatoes, taro, potatoes, onions, cabbage, peanuts, turnips, carrots, beets, asparagus, celery, rhubarb, bread fruit, limes, oranges, roselle, poha, bananas, strawberries, tomatoes, peppers, honey, rice, charcoal, coffee, etc. These consignments have come chiefly from Hawaii, Maui and Oahu. About 150 farmers are making regular shipments to the Marketing Division, and the number of consignments is more than 150 per month. A growth of monthly business from $300.00 to $5500.00 in 10 months must be considered quite satisfactory.

The Marketing Division issues weekly a list of the prices which have ruled for all kinds of local produce offered in the Honolulu market during the week. This list is furnished to all farmers who desire it and to all newspapers in the Territory. Advance notification and estimates are received from farmers as to the kinds and amounts of produce which they will have for shipment to Honolulu. About 100 letters are received weekly making inquiry as to the condition of the Honolulu market, the varieties of different produce preferred, the best time to ship and the best methods of grading and packing produce for shipment.

The Marketing Division keeps a list of the breeders of purebred stock, and thus serves as a directory for inquiring buyers. This is of mutual benefit to the breeder and buyer. It also helps to extend the raising of a better grade of stock.

The demand for reliable farm and garden seeds, of varieties preferred in the Honolulu market, has become so great that the Marketing Division will hereafter keep a supply of such seed by purchasing at the lowest wholesale price of reliable dealers, and selling to the farmer at cost price. A few local farmers are growing a good quality of seed-corn, cowpeas, etc. The Marketing Division finds a sale for such seed.

This Station has for several years strongly advocated the formation of cooperative societies among farmers to facilitate the marketing of produce, and for social and educational purposes. Four such associations are now in vigorous operation. These associations have greatly furthered the development of diversified agriculture in Hawaii. Their members number several hundred. When the farmers in these communities began to study marketing, they found in some communities, notably so on Kauai, that the plantations and general merchandise stores in their immediate neighborhood would take more miscellaneous produce than the farmers were then raising. The first market problems were, therefore, met in connection with the local home market. The surplus above the demands of the home market is sent to Honolulu. If an over-supply should threaten to accumulate in Honolulu, it is sent by the Marketing Division to San Francisco.

Much of the time and energy of the Marketing Division has been absorbed in bringing about better methods of handling, grading and packing produce. The modern market requires that all produce be graded according to size, color or quality so that each package shall contain one uniform grade of product. The pack must be honest. Produce must be clean, sound and of neat appearance. There is no place in the market for jumbled mixtures of job-lots or odds and ends. No farmer can establish a business without observing these fundamental requirements. Standardization of products and an honest pack are the foundation stones upon which alone the farmer can build up a business. Simple and obvious as these matters are, they nevertheless have to be learned anew in each community.

There are very few examples of similar experiments in governmental supervision of the marketing of farm products. Even the New Zealand plan is less direct. Hawaii is therefore among the pioneers in this work. The Territorial Marketing Division has proceeded upon no mere economic theories of marketing. There was a condition, not a theory, to meet. Hawaiian farmers declared, almost unanimously, that it was useless to raise farm produce, for the simple reason that the Honolulu market did not offer enough for it to pay the cost of production and freight. A restatement of economic principles offered little comfort. Before it was possible even to formulate a general plan of operations, it was necessary to bring more local produce to the Honolulu market, and to dispose of it at a profit to the farmer sufficient to encourage him to grow still more produce for the market. The mere fact that the city dealer makes a profit in handling farm produce does not in any way help to promote agriculture. The farmer himself must make a reasonable profit or agriculture will languish.

The Territorial Marketing Division therefore began at the beginning. A survey was made of the Honolulu produce market. The farmers were informed what kind of produce could be handled to the best advantage, what varieties were best to grow, how the produce should be graded and packed, and when it should be shipped. When the produce began to arrive, it was turned over directly to buyers at the best obtainable price. The presence of local produce in Honolulu gradually became known to dealers, army posts, hotels and other institutions. The demand for Island produce increased. The farmers were notified of this increased demand. More and more produce came to town. Moreover, the quality improved and the supply became more uniform. As soon as the shipments became so large that they could not be handled on the day of arrival, a store-room was leased on Queen street opposite Pier 15. Later it became necessary to lease another room for the more economic handling of the material. These are the simple steps in the movement to organize the agricultural market of the Territory.

In addition to the rapidly increasing amount of produce handled by the Marketing Division in Honolulu, mention should be made of the improvement of local markets on the other Islands under the influence of the substations and cooperative associations which have been established by this Station. The increased sale of farm produce from this influence is more than $1,000 per month.

Business Aspects of the Work.

As the result of the establishment of the Marketing Division, an active demand for seed of all kind has arisen, and greatly increased areas are being planted to miscellaneous farm and garden crops. This direct stimulation of agriculture is due solely to two facts. The Marketing Division provides a much larger outlet for local farm produce than has heretofore been offered, and the farmer receives a reasonable profit. Taking an average from the whole list of farm produce, it is found that, of every dollar which the consumer pays for produce at the retail store, the farmer receives 35 cents, while 20 cents goes for freight and hauling, 20 cents to the commission man and 25 cents to the retailer. In Honolulu, the Marketing Division secures for the farmer 10 to 20 per cent more for his produce than he would otherwise obtain. The average increase of returns to the farmer is above 15 per cent. It should be remembered also that much of what the Marketing Division now sells could not be marketed directly by the individual farmer. By adding the 15 cents to the 35 cents which the farmer would otherwise obtain, it is seen that the farmer gets 50 cents and the commission man 5 cents out of the consumer's dollar—a far more equitable division. This redistribution of the money obtained from the sale of farm produce benefits the farmer without increasing the retail price. A substantial encouragement is thus offered to the man with the hoe. There is no other way of building up an enthusiastic and efficient population of farmers. There is no other way of getting under cultivation the relatively large area of idle land in Hawaii.

How far can the production of miscellaneous farm crops be profitably increased? Until every acre of agricultural land in the Territory is producing all that it can be made to produce. Hawaii imports annually products to the value of $1,690,000, all of which could be produced in Hawaii at a profit. This material could readily be marketed through the machinery already set in operation by the Marketing Division. An organized system of cooperative marketing will solve the problem.

Through the agency of the Marketing Division the farmers are able to keep a more uniform supply of local produce in Honolulu. There is no other way of building up the trade in local produce. Farm produce is required for the table of the city dweller daily. The grocer must therefore have a regular, dependable supply. No single farmer can maintain a regular supply. No number of farmers, however large, can properly adjust the supply to the demand, if they ship independently to various dealers. The lack of organization was what kept the Honolulu market in a chaotic state. All the growers would ship their produce to Honolulu at the same time. Perhaps large shipments of the same kind of material had just arrived from San Francisco. As a result of this haphazard proceeding the prices were too low to pay freight and commission. Then the farmers would cease growing that kind of produce. A little later when the market was bare, the farmers would hear that the prices were high again. Then they would replant only to get another crop ready for a flooded market. This is an old story of what has recurred times without number in every farming community where marketing is unorganized.

With reference to the problem of adapting the supply of farm produce to the demand, the Territorial Marketing Division acts as a clearing house of ideas which will gradually bring about the desired improvement of conditions. By spreading practical information about coperative associations of farmers, the growers are helped to better methods of supplying their immediate local markets. By receiving constant information about the state of the Honolulu market, the growers are enabled to ship the right kind of produce to Honolulu at the right time. By getting constant advice as to the San Francisco, Portland, Seattle and Los Angeles markets, the Marketing Division is in a position to prevent a flooding of the Honolulu market by shipping produce to the mainland to the best advantage of Hawaiian farmers.

The Future of the Marketing Division.

Judging by the increased farm operations reported by the farmers and the still greater proposed extension of hog and poultry raising and general farming, the produce sent to the Marketing Division will reach a value of $10,000 per month within a year's time, or at the rate of $120,000 per year. This amount of business can easily be handled by the Division at an expense of $5000, or slightly more than 4 per cent of the business. This $120,000 annually will be largely new value, the creation of which was made possible by the establishment of a rational system of marketing. It may be safely asserted that the Territory could not expend $5000 more profitably. Even at present every dollar invested produces $11.50. When the volume of business mentioned above is reached, each dollar expended will produce $24. And even this small expenditure is in the line of straightforward, rational development; not paternalism. It helps the farmer to help himself. It helps the farmer to become the substantial, independent citizen which every community needs.

The experience of the past ten months has clearly indicated two directions in which the organization of the Marketing Division could profitably be extended—a branch office in San Francisco and a retail department in connection with the Honolulu office.

It will probably be necessary to establish a San Francisco branch during the next fiscal year. This branch will require nothing but one man and a convenient office room. The business of this man will be to make a study of the San Francisco markets, learn what produce can be disposed of there to better advantage than in Honolulu, and make a place in the San Francisco market for certain Hawaiian produce. As in all other lines of work, success will depend on the man. He will require an apprenticeship in cooperative marketing in the service of the Marketing Division before it will be wise to entrust the positon to him. It is hoped that the man will be ready for the place when the place is ready for the man.

There are several important things to be done in San Francisco. A better means of marketing Hawaiian coffee must be devised—a means by which Hawaii will get credit for growing the coffee and the grower get a better profit. It is necessary to learn what is the matter with the business of shipping fresh Hawaiian pineapples to the mainland, and how this business can be increased ten times or more. The San Francisco branch office will also have to find the right dealer to handle Hawaiian cooking bananas and sweet potatoes. There are hundreds of opportunities in the Pacific Coast markets which Hawaii now misses by reason of having no one in San Francisco to look after the interests of the miscellaneous agricultural industries. The few products just mentioned merely begin the list of Hawaiian materials of interest to the mainland.

The problem of a retail department of the Marketing Division in Honolulu is not a simple one. Hundreds of citizens of Honolulu are demanding it, and the demand is more insistent every day. The additional expense of operating a retail department will have to be borne by the farmers and consumers jointly. In other words, it should be a cooperative store, affiliated with the Marketing Division. Such an arrangement could probably best be brought about by a cooperative organization of consumers in Honolulu. If a cooperative store were established in affiliation with the Marketing Division, the ideal marketing system would be realized, namely, one in which all unnecessary links are eliminated from the chain which connects the producer and the consumer.

Ultimately each farming community will be organized into a cooperative association with a business manager who will attend to the shipment of all the produce of the community. The Marketing Division can then make returns to the business manager of each community. In that way the correspondence and bookkeeping of the Marketing Division will be greatly simplified.

For these first few months the Territory has borne all the expense of the Marketing Division. Henceforth the actual cost of labor and hauling will be charged against the produce, while the expense of supervision will be carried on Territorial funds. Both of these items of expense will automatically diminish to a low constant percentage as the volume of business increases.

Territorial supervision of marketing must be continued for some time—just how long it is impossible to predict at present. When the plan was set in operation, July 1, 1913, it was thought that after about four years of experience, the farmers would be sufficiently well organized to take charge of all the marketing operations. It would be a mistake, however, to withdraw Territorial supervision too soon. As a matter of fact, it is a good business proposition for the Territory to continue the supervision indefinitely since such striking results are obtained from so small an expenditure. It is merely a systematic effort of the

Territory to put agriculture on a paying basis and to distribute farm products in a businesslike manner.

ACKNOWLEDGMENTS.

The Territorial support of the Marketing Division was provided in Act 147 of the 1913 session of the Legislature. The men chiefly concerned in forwarding the movement were Speaker H. L. Holstein, Representatives G. P. Cooke, A. F. Tavares, S. S. Paxson and G. H. Huddy, and Senators H. B. Penhallow and A. J. Wirtz.

The farmers of Hawaii have promptly risen to the occasion. Their efforts are rapidly increasing the amount of fresh home-grown produce available to the Honolulu and San Francisco markets.

The Ad Club and the newspapers of Honolulu have repeatedly and most efficiently directed attention to the home market furnished by the Marketing Division.

The citizens of Honolulu have enthusiastically welcomed the opportunity for obtaining a larger quantity of fresh farm produce.

The Marketing Division could never have been brought to its present state of efficiency without the whole-souled service and complete devotion of the men upon whose shoulders the real work fell. Such a movement as the present system of marketing looks simple and easy when it is once set running smoothly. But perhaps no one, who has not been through the experience, can quite realize the thousands of trying situations and annoying troubles which must be met and adjusted into a harmoniously working system. Cooperative bookkeeping is a puzzling labyrinth, compared with ordinary business accounting. The machinery of the marketing system was set up and put in operation by Mr. A. T. Longley of this Station. With him was later associated Mr. O. B. Lightfoot. The rapid increase in business and the extremely low cost of handling the business are sufficient evidence of the efficiency of these men.

PRODUCE QUOTATIONS.

The prices quoted in the following market notes for Hawaiian produce are based on the experience of the Territorial Marketing Division during the past ten months and are therefore merely the prices which have prevailed during that period. The prices for many of the articles run along very uniformly with little variation from month to month. One of the effects of a well-regulated market is to steady the prices and prevent overflooding the market, and the consequent great fluctuation in prices. Farmers, however, must not assume that the prices given in the following notes will hold good for next year. The prices may be either lower or higher for any of the articles which are commonly handled in the Honolulu market. Moreover, the recommended methods of packing and shipment are necessarily of a temporary nature, and may be modified from time to time as experience accumulates regarding these matters.

MARKET NOTES FOR FARMERS

By A. T. Longley

Alligator pears are in great demand all the year, especially during the months when the supply is short. The market is over-supplied at the height of the season. The first shipments come in from Kona about March 1. At the height of the season it is doubtful if it would pay to ship pears from the other islands to Honolulu. The fruit should be shipped in orange boxes, well packed in excelsior or hay. Do not ship in bags. The long green bottle-necked variety is the favorite in the Honolulu market. Prices range from 35 cents a dozen for fruits coming in at the height of the season to $1.50 a dozen for early and late varieties. This fruit is not permitted to enter California.

Artichoke.—There is a limited market for this vegetable in Honolulu at good prices as imported artichokes are used entirely in Honolulu. Artichokes do well in the Olaa district and probably would do well in other sections with similar conditions. The price ranges from 60 cents to $1.80 a dozen n Honolulu.

Asparagus.—There is a growing demand for fresh island asparagus in Honolulu which could be supplied from the higher elevations of the islands. A great many people who now use canned California asparagus would use the fresh island product if it were in the market. Small quantities of fresh asparagus are imported from the coast and sell for 8½ to 15 cents a pound.

Bananas do well all over the islands and it is hoped that a line of fruit steamers between the islands and a coast port will soon be established. The common Chinese banana is probably the best known and is used for shipping to the coast. This variety should be left on the plant until full grown, but picked before beginning to turn yellow. When intended for shipment by railroad or steamer they should be wrapped with a good thickness of banana leaves to prevent bruising, and securely tied. Bananas bring from 30 to 60 cents a bunch, according to condition and number of hands. All bananas to be shipped to the coast have to be inspected for scale before wrapping.

The cooking bananas, Popoulu and Maia Mauli, are in constant demand locally, but several attempts to establish them on the Pacific coast have proved unsuccessful. Another attempt is to be made in the near future and the prospects for success are brighter than formerly. Practically all the cooking bananas used in Honolulu come from Kona, Hawaii. Only the largest and best bunches should be shipped and these very carefully wrapped with leaves to prevent bruising. Bruised cooking bananas turn black when ripe and are hard to sell. Good bunches of Maia Mauli or Popoulu bring from 75 cents to $1.25 in Honolulu.

Beans.—String beans are in great demand all the year round. The green-podded varieties are in greater demand, although the wax varieties are extensively used. The Canadian Wonder is probably the best of the green pods and the Refugee wax the best of the wax varieties for most localities. String beans should be shipped in well-ventilated boxes and when the price is high, in cold storage.

Fresh lima beans bring good prices all the year round. When shipped from the other islands to Honolulu they should be left in the pod and shipped in bags. The prices range from 2 to 4 cents a pound for limes in pod and as high as 11 cents a pound hulled.

There is an active demand for dried lima beans, practically all the year round at good prices. Most of the dried beans are imported from the coast. These should be thoroughly dried and shipped in bags. The price ranges from 5 to 6½ cents a pound.

Large quantities of small white or navy beans are imported from the States which could be grown at a good profit in the islands. The army is a large consumer of this variety of beans and could use them at about 5½ cents a pound. The small white bean has been grown in Kula, Maui, and on Kauai.

These should be thoroughly dried and shipped in bags containing 100 pounds net.

Calico and red Kula beans are very prolific bearers but do not bring as good prices as do the small whites. The local marnet for these varieties is limited but any surplus can be shipped to San Francisco for 3½ cents or better. The Portuguese, the largest users of beans in this Territory, prefer the Calico, a speckled bean, and the price is a shade better for this variety than for the Red variety. These two varieties are much attacked by the common bean weevil and when it is intended to keep them in storage any length of time they should be fumigated with hydrocyanic acid gas as soon as possible after harvesting in order to kill the weevil eggs which are sure to be present. These beans should be shipped in strong, clean bags containing 100 pounds net.

Beets.—The Honolulu market is well supplied with this vegetable by gardeners on Oahu and it is doubtful if it could be shipped to Honolulu from the other islands except for short periods when the demand is exceptionally great. Beets are imported from California in such emergencies now. The price ranges from 30 to 45 cents a dozen bunches. Beets should be put up in bunches of 4 or 5 with tops cut at 5 inches and shipped in well-ventilated boxes or with tops cutt off and shipped in bags.

Berries.—The strawberry is the only fruit of this order of commercial importance in the islands. Most of these berries sold in the Honolulu market are grown by Orientals in and about Honolulu. The only berries which come from the other islands in commercial quantities at the present time are from upper Olaa. Strawberries are prolific bearers in this region but owing to frequent rains it is often difficult to pick berries when dry for shipping. Berries picked in the rain will not keep 24 hours even in cold storage and consequently a good many shipments are received in poor condition. Strawberries should be picked a little green and shipped in crates of 12, 16, 24 one-quart wooden baskets. The price of berries from the other islands ranges from 17½ to 30 cents a quart, depending upon the season of the year and the condition of the berries.

Wild red raspberries or thimble-berries grow in profusion along the roads and in the forests of the rainy sections of the islands and there ought to be some use as food to which they could be put. Previous shipping experiments showed that they could not be sent to Honolulu by ordinary freight from Maui and Hawaii. Perhaps they could be shipped in cold storage. These berries make excellent pies and preserves and if they could be delivered in Honolulu in good condition a market could no doubt be found for them at a profitable figure. These berries should be shipped in the same containers as recommended for strawberries and in cold storage.

Breadfruit can be sold in small quantities in Honolulu at fair prices. It should be shipped in well-ventilated crates holding two or three dozen fruits. The price ranges from 50 to 75 cents a dozen.

Brussels sprouts are imported in refrigerators from California in season. These are shipped in barrels, but smaller containers would probably be better. The price ranges from 10 to 15 cents a pound.

Broom corn grows well in many parts of the islands and enough should be grown to furnish material for all the brooms used in the islands. The broom corn grown on several of the islands has been pronounced better than the general run of this product from California and compares favorably with that of the Central States. There is a broom factory in Honolulu which is importing its brush from California and would be glad to buy it at home at coast price. Broom corn should be thoroughly dried, seeded and tightly baled for shipment. Good brush brings from 5 to 7 cents a pound.

Butter.—New Zealand butter is being sold in Honolulu far below the price formerly obtained for good island butter. A good market could be worked up for the home product at the same price or a little better than that received for imported butter.

Dairymen making butter to be sold in Honolulu should be sure that every pound sent in is perfect in every respect. It should be made from properly ripened cream that is produced by clean, non-tuberculous cows, properly handled and milked. The room where the butter is made and the churn can not possibly be too clean. Butter should always be shipped in cold storage, or in boxes containing ice. Each butter-maker should put his butter up in one-pound packages with his own print if possible, or a clean attractive wrapper bearing his name and brand and his guarantee as to purity, etc.

There is a growing demand for strictly fresh buttermilk in Honolulu and any buttermaker who can conveniently ship his buttermilk to Honolulu can get several times its value as pig feed. It should be shipped in 5-gallon milk cans in cold storage. The price ranges from 15 to 18 cents a gallon.

Cabbage is one of the most extensively used vegetables in Honolulu. From May to January there is a good market for cabbage from the other islands. During these months large quantities of cabbage are imported from California that could be raised at a profit at some of our higher elevations if it did not cost too much to get them to market. During the months of February, March and April large quantities of cabbage are sent to Honolulu from Wahiawa and other sections of Oahu and the price drops as low as 35 to 40 cents a bag. Cabbage which has much handling should be shipped in crates unless it is very solid. The best shipper is perhaps the Winninstadt. This variety gives a solid, medium-sized head that can be shipped in bags. The price of cabbage ranges from ½ to 3½ cents per pound.

Carrots.—The carrot is a very prolific grower in Hawaii and should be grown in large enough quantities to supply the local market. Carrots are generally sold in the market in bunches of five or six. They are also imported from California with tops off in bags. The price is 40 cents a dozen bunches for local carrots and from 1 to 2 cents a pound for the California product.

Cauliflower.—Island Cauliflower has never been a success on the Honolulu market. It is reported to be yellow and bitter. These objections could probably be removed if the vegetable were properly cultivated. The heads should be individually wrapped in paper and shipped in oranges boxes in cold storage. The price of California cauliflower delivered in Honolulu ranges from $1.50 to $1.75 a dozen.

Celery.—At one time excellent blanched celery was grown in several sections of the islands and shipped to Honolulu. Of late years, however, the celery blight has destroyed the industry in the sections where it once flourished. The island celery that comes into the local market at the present time is not blanched but generally of a rank green color. This celery can not be used for table purposes and is sold at low figures for flavoring soups and salads. Celery should be shipped in standard celery crates holding from 6 to 7 dozen large stalks. Green island celery sells for from $1.00 to $2.50 a crate. A great many crates of California celery are imported each year at high prices which could be profitably grown in sections where the celery blight has not made its appearance.

Charcoal.—The charcoal market is controlled by the Japanese peddlers and it is difficult to sell any amount of this product from the other islands at a paying figure. Guava and wiawi charcoal is considered better than kiawe. Most families prefer the small bags holding about 16 pounds, but it would be more convenient and cheaper for producers on the other islands to ship in barley bags that would hold about 50 pounds.

Chickens are always in demand in the Honolulu market, especially fat young broilers and roasters. Poor chickens are never in demand and should be fattened before being shipped in. Young cockerels of the medium and heavy breeds bring as high as 37½ cents a pound. Old stock bring less. Chickens should be shipped in a strong light crate to comfortably hold a dozen. Do not crowd them in the crate. The crate should be high enough to allow the chickens to stand upright, and be sure that the chickens get water before starting. Put enough feed in the crate to last them to Honolulu. A uniform pen of chickens will sell more readily than a lot of scrubs, no two of which are alike. Therefore, pick out a breed and gradually do away with any "dunghills" you may have. It will pay you. Remember this: It does not pay to send poor chickens to the market. Fatten them up first.

Cocoanuts.—There is an increasing demand for this product on the Pacific coast and a great many tons of cocoanuts that are now practically going to waste on the islands could be shipped in the fresh state at a good profit, or where there were enough trees to warrant it, manufactured into copra, the market for which is very good. Fresh cocoanuts should be husked and shipped in strong bags.

Coffee should be shipped to Honolulu in 100-pound bags with parchment removed. When possible the berries should be graded.

Corn, Field.—Field corn does well in a great many sections of the islands. It has been shown that as good a quality of corn can be produced on the islands as is imported from the states in large quantities. All the corn that is used in the Territory should be produced at home and importations from the Pacific Coast stopped. In addition to the present demand for corn the United States Army would use large quantities if it could be bought as cheaply as barley.

The Honolulu market demands a small-grain yellow corn, which is principally used for feeding poultry. White-grain corn, no matter how small, is undesirable. King of the Earlies, a 90-day dent corn, and Improved Leaming are probably the best varieties to raise for this market. Corn should be thoroughly dried and shipped in good strong bags, 100 pounds net to the bag. Beware of poor bags.

Corn, Sweet.—Sweet corn is probably the best seller of all vegetables in the Honolulu market and always commands good prices. It should be shipped in barley bags as soon as possible after picking. There should not be more than 24 hours between the time of picking and the time it is put on the market. Country Gentleman and Oregon Evergreen are two varieties that have produced well in the Territory.

Cotton should be ginned and baled if possible before shipping to Honolulu. Cotton being very bulky and light, is baled very tightly in order to save freight. Caravonica cotton is recommended by the U. S. Experiment Station as the best for the islands. The price ranges from 17 to 22 cents a pound.

Cream.—A great quantity of cold-storage cream is imported from the Pacific Coast annually that should be produced in the islands. The ice cream manufacturers are probably the largest users. Cream should be shipped in regular cans in cold storage. All cream should test at least 30 per cent butter fat and less than 2 per cent acidity upon arrival.

Cucumbers.—The long green variety is preferred in this market. They should be shipped in well-ventilated boxes to prevent heating. Pack closely to prevent bruising.

Ducks.—The most popular duck in the Honolulu market is the Muscovy. Muscovy ducks should be sent to market at the age of five to eight months. If properly fed and cared for they should be fat and weigh from 4 to 8 pounds. When a Muscovy duck gets more than nine or ten months old it has a strong flavor that is undesirable. Keep your ducks fat and send them in at the proper age.

Pekin ducks are not in as great demand as the Muscovy but bring good prices. India Runner ducks are smaller than either of the above-mentioned breeds, but would find a ready market as broilers.

The common mud duck raised on fish ponds is a very poor specimen and cannot be compared with any of the above-mentioned breeds for flavor. It is hoped that better breeds will soon drive this class of ducks from the market.

Eggs.—All eggs shipped to market should be put up in standard 30-dozen shipping crates or in 12-dozen shipping crates with fillers, and the shipper should be sure that every egg in the box is strictly fresh; not more than one week old when shipped. Eggs should be gathered at least once a day and kept in a cool, clean place until ready for shipment. When packing a case of eggs for the market cull out all small, poorly shaped, dirty or doubtful eggs. Do not wrap eggs in paper or bury them in rice hulls, bran, coffee parchment, etc. It requires too much labor to unwrap papers and dig eggs out of rice hulls. Purchase enough egg-carriers or crates of the sizes you will need to carry on your shipments and save yourself time and expense. All eggs received at the Marketing Division in anything except boxes containing fillers will be charged for the labor of unpacking. If any farmer cannot get shipping crates the Marketing Division will be glad to get them for him at cost price. The standard weight for 1 dozen eggs is 23 ounces and your eggs should weigh at least that much. White-shelled eggs are preferred for table purposes and all eggs should be graded according to color.

Duck eggs should also be graded and shipped in crates with fillers. India Runner ducks lay large clean eggs, the flavor of which is claimed to be as good as that of a hen egg. The price of chicken eggs ranges from 30 to 65 cents a dozen during the year. Common duck eggs sell for as low as 24 cents a dozen.

Eggplant is supplied to the Honolulu market by gardeners on Oahu and could probably not be shipped from the other islands at a profit. An orange box would make a good package for shipping.

Figs should be picked when full grown and beginning to get soft and shipped in crates holding from four to ten 6-pound wooden baskets. The demand is generally good and the price ranges from 75 cents to $1.00 a hundred.

Geese are not in great demand the greater part of the year. At Christmas the demand is slightly stimulated and a great many more birds could be sold than are sent to the market. Geese should be shipped in tall crates that comfortably hold six birds.

Grapes.—The Isabella grape is the only one that is grown commercially in the islands. As a general rule these grapes are picked and put on the market before they are thoroughly ripe and are consequently more or less sour. The grapes should be allowed to remain on the vine until they are full grown and sweet. The Honolulu market is well supplied by the growers on Oahu at about 7 cents a pound. Grapes should be shipped in the same crates as recommended for figs.

Grapefruit is about the easiest of all citrus fruit to grow in Hawaii and its culture should be taken up on a commercial scale. Many cases of this fruit are imported from California annually which could be produced in the Territory. Grapefruit should be shipped in regulation cases holding 80 fruits. The price ranges from $4.00 to $6.50 a case.

Hides are higher at the present time than they have been in years. When the animal is butchered the hide should be immediately spread out flat on the floor and covered with a liberal amount of coarse salt, being sure to leave no spots uncovered. If more than one animal is being butchered the hides can be put one upon the other, the hair side always down. Special care should be taken not to cut holes in the hide when skinning the animal, as they depreciate its value.

Dealers prefer salted hides to pickled hides. The pickled hides are apt to be too wet and cause trouble. There are four kinds of hides with their different grades. They are steer, heavy, medium and light; cows, heavy, medium and light; bulls and kipps. Heavy steer hides bring the best prices. Bull hides bring the poorest prices owing to the fact that the skin is not of uniform thickness. Hides should be shipped in bundles containing two each folded together so as to make a neat package and tied with a small rope, or put in a bag. The price ranges from 7 cents for bull hides to 14 or more for heavy steers.

Honey should be extracted from the comb and shipped in 5-gallon tins. Recleaned kerosene oil tins will answer. The price ranges from 7 to 14 cents, depending upon the grade of honey.

Kale is very seldom seen in the Honolulu market. A market might be worked up for a small quantity.

Kohlrabi grows very well in many parts of the islands and is a good shipper. It should be picked when young and tender and not allowed to grow three or more inches in diameter, to become woody and tasteless. Kohlrabi should be tied in bunches of five good-sized tubers and shipped in bags or crates.

Leek is the spring onion, a very perishable product. It is not likely that it could be profitably raised on the other islands for shipment to Honolulu. They should be put up in bunches of 1¼ pounds, and shipped tops uncut, in well-ventilated crates. The price is 40 cents a dozen bunches.

Lemons.—There are only a few smooth-skin lemons grown in the Territory and there is not a commercial orchard of any kind. There are a few scattered trees of the rough lemon, but this variety is not wanted for table use on account of the roughness of the skin. California lemons sold for as high as $7.50 a case of 300 during the past year. This fruit should be well cured and packed in cases for the purpose.

Lettuce.—The lettuce market is well supplied by Oriental gardeners on the island of Oahu. A great many people, however, prefer to know where and under what conditions lettuce is grown. For fancy trade it might pay to grow lettuce on the other islands for Honolulu if it could be shipped to arrive in good condition. It should be shipped as dry as possible in well-ventilated crates. The smooth-leaf variety is in greater demand in this market.

Limes.—Limes are in demand in Honolulu throughout the year, with the exception of cool weather. When lemons are high the demand for limes is greatly increased. Do not pick limes that are too green; let them get full grown before sending them to the market. Large, well-graded limes are never hard to sell at good prices. This fruit should be shipped in boxes or bags, boxes preferred.

Loganberries.—The Loganberry is very little cultivated in Hawaii. It seems possible to establish a market for this product if it can be shipped to arrive in good condition. They should be shipped in the crates recommended for strawberries.

Mangos are plentiful in Honolulu during the season, but early and late varieties not infested with fruit fly might be shipped to Honolulu from the other islands at a profit. They should be picked when full grown but firm and shipped in orange boxes.

Onions.—Bermuda onions do well in a great many localities in Hawaii and a larger acreage should be planted to this crop.

If planted early the crop should come in in time to catch the Pacific Coast market bare and command high prices. If planted late the crop will come in with the California and Texas onions and consequently have to compete with them as well as the Australian onions. The early onions should be put up in crates holding 50 pounds net; later they may be sold in bags of 100 pounds each. Be sure that onions are well dried before putting them in crates or bags. The U. S. Army in Hawaii uses 26,000 to 30,000 pounds of onions monthly. Prices range from $2.00 to $5.00 a hundred pounds.

Oranges.—Hawaiian seedling oranges are in demand the greater part of the year. They should be picked when full grown and nearly all yellow and shipped in orange boxes, not in bags or packing boxes. Grade the oranges when packing according to size, color and general appearance. Do not ship poor oranges in the same box with the best ones. The price of Hawaiian oranges ranges from 50 cents to $2.00 a hundred.

Papaia.—The demand for good papaias is increasing and the market could use a large quantity of choice fruits that could be raised on the island of Oahu to take the place of many tons of scrub varieties now sold in the market. It probably would not pay to ship them from the other islands. Fruits to be shipped to the market should be picked when they begin to turn yellow and packed on end in a wagon, or box holding a single tier.

Peas.—Fresh green peas of good flavor are always in demand in the Honolulu market but peas that are tough and bitter cannot be sold at any price. Grow only good sweet varieties and send them to the market in well-ventilated boxes, not bags. They are apt to get stacked on the wharf if shipped in bags. The price of peas ranges from 7 to 12½ cents a pound.

Peas, Dried.—Hawaiian dried peas were put on the market for the first time this year and have made a name for themselves. For dried peas a prolific bearer should be used, but at the same time a pea that has a good flavor. The common Kula pea, while a prolific bearer, is deficient in flavor. Peas should be thoroughly dried and shipped in bags containing 100 pounds. The price ranges from 3½ to 5 cents a pound.

Peanuts are imported in large quantities from Japan and the Pacific Coast that should be raised here. The two varieties used by the Honolulu market are the small Spanish and the Jumbo. The latter brings about 6 cents a pound and the Spanish 5 to 5½ cents. Ship in bags or bales. Be sure that the peanuts are properly cured before shipping.

Peppers, Bell.—Bell peppers are in demand in the Honolulu market a great part of the year at good prices. The pepper should be picked as soon as it is full grown but before it begins to turn red, and shipped in well-ventilated cases. Orange cases would do very well.

Peppers, Chili.—Fresh Chili peppers are not in great demand in Honolulu, but there is a good market for dried chilis on the Pacific Coast. None of the common Hawaiian varieties are suitable for drying and shipping, according to authorities. The Anaheim chili is recommended for shipping in the dried state.

Pineapples.—It would probably not pay farmers on the other islands to ship pineapples to Honolulu. Most of the fresh pineapples in the Honolulu market are brought in by wagons. If shipped by the railroad they should be sent in lug boxes. It is possible that the fresh fruit shipments to the Pacific Coast can be increased, thus making a market for a great many pineapples. The fruit will otherwise be produced this year at a loss, due to the extremely low prices offered by canneries. Pineapples to be shipped to the Coast should be picked when full grown but before they have begun ot turn yellow, and packed in clean excelsior by experienced packers. All pineapples and packing have to be inspected by the agent of the Bureau of Entomology, U. S. Department of Agriculture, Honolulu, before going aboard ship.

Popcorn.—There is a small market for popcorn in Hawaii that should be supplied by our own farmers. The corn may be either shelled or sent to the market on the ear. It would probably be better to shell the corn, however, in order to save freight.

Potatos, Irish.—There is a ready market in Hawaii for every

Irish potato that can be produced for years to come. The army contract alone is 240,000 pounds a month. The ravages of the potato blight would be greatly reduced if our farmers would use new seed each year instead of planting the potatoes that are too small to sell. There is a good market for new potatoes all the year round. Dig up any potatoes that have been attacked by blight and put them on the market as new potatoes. New potatoes should be shipped in crates, as they are apt to get bruised in bags. Old potatoes should be shipped in bags of 100 pounds each.

Sweet potatoes.—There are a great many varieties of sweet potatoes grown commercially in Hawaii, a few of which are good, but by far the larger part poor. The red-skinned yellow-fleshed variety, Apo, brings the best price of any of the Hawaiian varieties. The yellow-skinned pink-fleshed variety is the next. White-fleshed sweets are not generally wanted and in the season when the first two-mentioned varieties are plentiful and cheap it is hard to sell them at any price. The Jersey sweet, which is the commercial sweet potato of the Pacific Coast, does not thrive well in Hawaii as a general thing and is much attacked by pests.

Perhaps the best sweet potato to grow in Hawaii is a variety recently imported from Madeira by Mr. A. Santos, a homesteader of Homestead, Kauai. This potato is a good bearer, furnishes as abundance of green food for stock, and the flavor is at least as good as that of the Jersey Sweet. This variety should be more extensively cultivated for the market.

Sweet potatoes should be dug in dry weather if possible. They should be graded as they are put in the bags and all cut, decayed or small potatoes kept out for home consumption or stock food. The price of sweet potatoes ranges from 85 cents to $2.00 a bag.

Radishes could not be raised at a profit on the other islands to ship to Honolulu. The market is well supplied by gardeners on Oahu. Radishes should be put up in bunches of 5 or 6 and delivered to the market fresh every morning.

Rhubarb.—It is claimed by dealers in Honolulu that Hawaiian rhubarb does not have as good a flavor as that which is imported from California. They make a difference of 2 to 6 cents a pound. Rhubarb should be pulled when full grown and shipped in apple boxes. It should not be shipped in bags, as is the custom in Hawaii, because the stalks are so easily broken in transit.

Roselle has been grown successfully in all parts of the islands and although there is only a small market for fresh fruit there is a good market for the dried calices for jam and jelly. It is very likely that a factory will be opened in Honolulu to manufacture roselle jam and jelly in the near future. The price quoted by a Chicago firm for dried roselle this year was 40 cents, or 4 cents a pound fresh.

Sheep are not bought in this market by live weight. The butchers prefer to dress them and buy them by dressed weight. It would therefore be better to dress sheep at home and ship the carcases in cold storage when possible.

Mutton brings about 10 cents a pound.

Squabs are always in demand in the Honolulu market. The Carneaux or Homer pigeons are the best for squabs. Squabs bring from 30 to 45 cents a pair, depending upon the size and breed. Squabs should be killed and picked and shipped in cold storage.

Squash and Pumpkin are not in great demand in the market. They should be shipped in bags or crates similar to those used for cabbage.

Taro.—A great deal of taro is used for cooking in addition to making poi. The irrigated taro is considered better than upland taro for both purposes. The price of taro ranges from 90 cents to $1.30 a hundred, depending upon what per cent of poi can be made from it. It should be shipped in strong bags. Taro for cooking purposes should have six or eight inches of the tops and be tied in bunches of 3 or 4, weighing about 6 pounds.

Tomatoes.—Good tomatoes are scarce in the Honolulu market as a rule and good prices prevail. Of course this vegetable is attacked by the melon fly and is hard to bring to a ripe state on the vines. As a general thing the tomatoes should be picked when they have altained their growth, and shipped to the market in crates. Orange boxes would answer the purpose very well.

Turkeys.—A great many cold-storage turkeys are imported from California that could be produced in Hawaii. Turkeys should be fattened on grain before shipping to market. Ship in crates that will comfortably hold half a dozen birds, or a double crate with a partition in the middle. It is well to put a little straw in the crate and a few handfuls of corn. Keep the sexes separated. The wholesale price of turkeys ranges from 30 to 35 cents a pound.

Watermelons.—Owing to the prevalence of the melon-fly in Hawaii, it is difficult to raise watermelons. Consequently they are very high in price and always in great demand. Often a good crop of watermelons can be grown in a locality where no melons have been grown before, with little or no trouble from the fly. It is seldom, however, that two crops can be taken from the same land without trouble from the pest. Watermelons should be shipped in bags or in cabbage crates. The price ranges from 20 to 75 cents each.

Paradise-Pacific Print.

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Issued Oct. 10, 1914

Hawaii Agricultural Experiment Station

HONOLULU

E. V. WILCOX, Special Agent in Charge

PRESS BULLETIN NO. 47.

Cold Storage for Tropical Fruits

By E. V. Wilcox
and
C. J. Hunn.

Introduction.

So far as may be judged by the literature on cold storage available to this station, no systematic experiments have been made in cold storage of tropical fruits except citrus fruits and bananas. Even with these fruits experiments have been largely confined to a study of the proper temperatures to apply during transportation. Benson* reported that mangos and pineapples could be safely held in cold storage for four to six weeks, but that passion fruit could not keep more than two weeks in cold storage. At various times this station has made tests which indicated that mangos and avocados would preserve their flavor and texture for four to six weeks in a commercial refrigeration room for fruit.

The supply of tropical fruit on the Honolulu market is irregular. The market is sometimes flooded and sometimes bare. The station is attempting, through its marketing division, to adjust the supply of fruit more uniformly to the demand. It became necessary to know, however, whether cold storage was applicable to tropical fruits as it is to apples, pears, etc. Through the courtesy of the Hawaiian Electric Company, the station was offered the use, for experimental purposes, of several refrigerator rooms maintained at different temperatures. In the experiments reported in this bulletin a study was made of the effect of cold storage on star apple (*Chrysophyllum cainito*), avocado, fig, papaya, water lemon (*Passiflora laurifolia*), strawberry guava, pineapple, and mango, and also upon the eggs and larvae of Mediterranean fruit fly in these fruits. It was considered important to determine the degree of refrigeration and length of time required to kill this pest, particularly in mangos and avocados.

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* Agr. Gaz. N. S. W. 4 (1893) pp. 870-877.

TEMPERATURE OF THE REFRIGERATION ROOMS.

Throughout the six months occupied by the experiments, the temperature of each room remained very uniform. The temperatures reported in the following pages are the average temperatures for the whole period. In the 32° room the temperature ranged from 30° to 33°; in the 36° room, from 33° to 38° F.; and in the 45°, from 40° to 47°. Continuous thermograph records were kept, and checked by certified thermometers. The air was reasonably dry in all three rooms.

STAR APPLE.

Large purple, small purple and green varieties of star apple were used, 73 fruits in all. Of these fruits 33 were held at a temperature of 32° F. and 40 at 45° F. All but 11 of the fruits had been bagged onthe trees to prevent infestation with fruit flies. The uninfested fruit was cured two days in a fruit room at the station before being placed in cold storage.

Four large purple star apples picked in a green condition, showed slight shriveling of the skin after being held six days at a temperature of 32° F. No other noticeable changes took place during the next 50 days, at the end of which the fruit was removed and examined. The pulp was found to be firm and corky. The fruit did not ripen well after removal from refrigeration.

Fruits of the green variety of star apple were picked when nearly ripe, and held at 32° F. for one month. A slight shriveling of the skin appeared after ten days. Small mold spots developed on

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one fruit during the month. When removed for examination after 30 days of refrigeration, the fruits showed a slightly discolored and somewhat shriveled rind. The pulp was perfect in color and texture, and the flavor excellent. The pulp was more attractive in appearance than when picked fresh from the tree.

Small purple star apples were picked in a green condition and held at 32° F. for 58 days. In this varitey as in the case of all other fruits reported on in this bulletin samples were removed for examination at weekly intervals. At the end of two weeks the flavor and appearance of the pulp were excellent. The same was true at the end of the month. One fruit showed mold on the rind and fermentation in the pulp.

Small purple star apples were picked in a half ripe condition and held for 36 days at 32° F. The skin gradually faded and shriveled after the second week. At the end of the period the pulp of the fruit was firm, of good color and perfect flavor. The same variety, picked ripe, kept well for 30 days, but at the end of a period of 57 days had deteriorated in color and appearance externally, while the pulp was still perfect in flavor.

Specimens of the same varieties of star apples, picked green, half-ripe and ripe were placed in refrigeration at a temperature of 45° F. for a period of 40 days. The same changes were observed as in fruit held at 32° F. The deterioration was somewhat more rapid, however, and molds developed more extensively on skin abrasions. The color of the skin was better preserved at 45° than at 32° F. The texture of the rind, however, and the texture and flavor of the pulp were much better in the fruit held at 32° F.

From these tests the conclusion may be drawn that star apples intended for cold storage should be picked in a half-ripe condition, cured in a well ventilated room for about two days, and then held at 32° F. for not longer than three weeks. A discoloration and fermentation of the pulp begins sooner in fruit infested with fruit fly than in uninfested fruit.

Figs.

Figs of several common varieties were placed in cold storage at

32° and 45° F.. The fruit was in the proper degree of ripeness for table use when picked. It was held for one day in the Station fruit room before going to refrigeration. After 12 days at 32° F. a few of the figs showed mold on the rind, but the mold had not penetrated the pulp. The color of the pulp was good and the flavor had suffered no change. The remainder of the fruits were in excellent condition without any signs of mold on the surface when examined after 17 days. A few mold spots appeared after 22 days. The flavor and physical condition of the pulp was still perfect at the end of a month, but after 44 days the flavor began to deteriorate and the fruit began to absorb an odor resembling ammonia. A part of the figs had been exposed to infestation with fruit flies. These fruit, held at a temperature of 32° F., kept their flavor and condition until fermentation set in about the infested areas at the end of 30 days.

Figs held in cold storage at 45° broke down sooner than those held at 32° F. At the end of 40 days all the figs in the 45° room showed mold on the outside of the skin, and most of them had deteriorated in flavor and appearance.

On the whole figs, even when picked in a ripe condition, seem to be adapted to cold storage at 32° F. for a period of about one month. As a result of refrigeration the pulp is firmer and more attractive in appearance than when freshly picked from the tree, and the flavor is about equal to that of the freshly picked fruit.

PAPAYAS.

Papayas of six varieties were used in testing their adaptability to cold storage. They were placed in two refrigerator rooms with a temperature of 32° and 36° F. respectively. The fruit was picked in three stages, green, half-ripe and approximately ripe. Those which were nearest ripe were all yellow in color, but were still firm. After 27 days in storage, most of the papayas began to show small mold spots on the skin. These spots increased in size rather rapidly and the fermentation extended into the pulp of the fruit. Aside from the development of mold on the skin, the texture and flavor of the fruit was perfectly preserved. There was a tendency, however, to develop a slight cold storage odor, due to the absorption of ammonia. Papaya fruits which had been punctured before going to cold storage began to ferment and decay badly within 24 hours after removal at the end of a month of refrigeration. Even the use of a formalin wash on refrigerated papayas failed to prevent the rapid development of mold on the rind after the fruit had been removed from cold storage.

The same results were obtained with the papayas which were held at 36° F. The fruit appeared to keep as well at this temperature as at 32° F. The mold did not develop very rapidly in the case just mentioned.

On account of the relatively extensive growth of mold on the rind of papayas, another test with this fruit was made in which the fruits were carefully washed in a three per cent solution of formalin and then thoroughly dried and placed in paper bags before going to cold storage. The fruit in this test was nearly ripe when picked. The use of formalin in this manner seemed to prevent the development of mold. All of the fruit was still in perfect condition at the end of one month. After 40 days the pulp was found to be ripened to about the softness which is desirable for table use. Some of the pulp was slightly watery, but no more so than occurs normally in the ripening of papaya. The flavor was good, with little or no evidence of a cold storage odor.

At a temperature of 36° F., fruits similarly treated with formalin before being sent to refrigeration kept equally well with those in the 32° F. room, except for the appearance of a few spots of mold. The preservation of the fruit was practically perfect for 45 days, at the end of which time the fruit had completely ripened with a good flavor.

Papayas seem not particularly adapted to cold storage on account of the tendency to the development of molds. The common mildews or molds grow very rapidly in the dry papaine or juice of the papaya which exudes from minute skin punctures. It is practically impossible to find a papaya fruit without skin punctures on account of the great delicacy of the skin. Even small grains of sand carried by the wind abrade the fruit. The juice exudes at once and dries and in this material molds rapidly develop. Furthermore there is little necessity for holding papayas in cold storage except for transportation, for the reason that the fruit ripens the year round.

The waterlemon (*Passiflora laurifolia*) used in this experiment was obtained from a regular shipment of the fruit which had been sent to the Territorial Market. They were of the common yellow variety, and had received no special care in transportation, being shipped loose in barrels. This fruit kept in perfect condition in both the 32° and 36° F. rooms for a period of three months. At the end of that time the appearance of the rind, the fibrous bag inside the rind, and the pulp of the fruit was the same in all respects as when the fruit was put in cold storage. The flavor underwent no alteration whatever during the whole three month period. As in the case of other fruits, samples were taken out each week for examination. Waterlemons seem to be the best adapted to cold storage preservation of all the fruits with which experiments were made. It is difficult to understand why there should be so much difference in keeping properties between the Hawaiian waterlemons and the passion fruits with which Benson experimented in Australia. The waterlemons after being kept for three months in cold storage were found to hold their flavor and physical appearance for four days after removal from refrigeration.

STRAWBERRY GUAVA.

A few fruits of the strawberry guava (*Psidium cattleianum*) were placed in cold storage in the 32° and 36° F. rooms. This fruit is one of the preferred host plants of the fruit fly, and a part of the fruit used in the experiment was infested. The fruit was picked in a nearly ripe condition. The strawberry guava is not well adapted to cold storage. Practically all of the fruit was shriveled and fermented or decayed within one month in both the 32 and 36° F.

rooms. Mildew developed abundantly on the rind and only a few of the fruits kept their normal flavor and appearance more than two weeks.

MANGOS.

The mango season in Hawaii, while a long one, could be extended to advantage by means of cold storage, particularly of the better flavored varieties. The only two varieties which we used in this experiment were Java No. 1950 and No. 1977. Boxes of both of these varieties were placed in the 32° and 36° F. rooms. The fruit in all cases was held in the station fruit room before going to refrigeration. The most of the fruit had been bagged on the trees, and was therefore not exposed to fruit fly infestation. Some of it, however, had been stung by the fruit fly. In the 32° F. room the appearance of the fruit remained normal in every way for the first month. The rind then showed slight shriveling and a deadening of the color. Fruit removed at this time were found to possess a normal pulp in perfect preservation, with good flavor and with no noticeable changes. The subsequent changes consisted in a shriveling of the skin which injured somewhat the appearance of the fruit. The pulp, however, remained in good state of preservation for a period of two months, possessing at the end of that time a normal flavor. After refrigeration for two months the fruit was removed to the station fruit room at an ordinary temperature for a period of two days. At the end of that time the flavor of the fruit was found to be slightly flat. This was more noticeable in the fruit which had been held at 36° F. than in that which was in the 32° F. room.

Mango No. 1977, some of which was picked in a perfectly ripe condition, preserved the normal texture and flavor for a period of 35 days. After that the flavor deteriorated slightly, but was by no means abnormal. The flavor of the green fruit of this variety was also perfectly preserved for a period of two months. No fermentation or other change took place in the fruit within two days after removal from cold storage.

PINEAPPLES.

Pineapples of the smooth Cayenne variety were tested for their adaptability in cold storage in a green, ripe and half-ripe condition in the 32° and 36° F rooms. In the 32° F. room after one month, ripe pineapples showed a slight deadening of the normal yellow color. The rind otherwise was in perfect condition with the exception of a few mildew or mold spots which did not penetrate into the fruits. The flavor at the end of one month was excellent, and equal in most cases to that of the pineapple freshly cut from the plant. In a few cases the acidity seemed to be less than is normally the case, at least as judged by the taste. No chemical tests were made. After 45 days the leaves of the crown appeared to be slightly withered and minute traces of softening extended for a short distance into the pulp from two or three eyes. These phenomena appeared only in the ripe and half-ripe fruit. In the green fruit preservation was still perfect at the end of 45 days. Essentially the same results were obtained in the 36° F. room, except that the flavor of the pineapple began to deteriorate after 35 days in the case of the fruits placed in refrigeration at a ripe state. There was also a greater tendency for the development of a superficial mold which did not, however, penetrate the pulp. From these experiments the conclusion may be drawn that half-ripe and ripe pineapples may be held in cold storage at a temperature of 32° F. without harm to the color or flavor of the pulp of the fruit. The only change is a slight deadening of the color of the rind.

AVOCADOS.

With the considerable number of varieties of avocado which are now grown in Hawaii the season of this fruit has been extended to cover six months or more a year. It was desirable to know, however, whether some of the better varieties could be held for a month or more in cold storage in order to prevent the loss which occurs when the fine varieties are shipped in such quantities as to flood the market. Only a few fruits of the hard-shelled Guatamala variety of avocado were available for testing. These fruits were kept in the station fruit room one day before going to cold storage and were then held in the 32° and 45° F. rooms for a period of 65 days, being examined in storage at weekly intervals. A few of the fruit had been picked too green and did not ripen or show any tendency to soften during the test. Those which had been picked half-ripe began to manifest an approach to table ripeness after a period of one month. At the end of two months the pulp was found to be of normal color and excellent flavor with no apparent alterations due to cold storage.

In further cold storage tests of avocados, boxes of miscellaneous varieties were used from Kona and the island of Oahu, and a few boxes of finer flavor from those bearing station numbers 1855 and 1871. In all cases the fruit preserved its normal color, appearance, texture and flavor for a period of two months in either the 32° or 36° F. room. There was in no case any discoloration of the pulp or fermentation or apparent loss of flavor. The color of the skin became slightly deadened after 75 days, but the pulp was still in perfect condition.

When removed from cold storage after a period of 60 days the fruit which had been kept in the 32° F. room held up longer than that from the 36° F. room. Avocados picked green and held in cold storage for two months ripened with good flavor within three days after removal from cold storage and held their flavor well for a period of six days. The avocado seems to be well adapted to cold storage at a temperature ranging from 32° to 36° F. for a period of at least two months.

EFFECT OF COLD STORAGE ON GERMINATION OF SEED.

Seed from several varieties of star apple were planted after the fruit had been in cold storage various lengths of time. Seed from fruit held at 45° F. for various periods up to 25 days germinated promptly to the extent of 90 per cent. Seed from fruit held for more than 30 days in cold storage failed to germinate at all. Similarly with the seed of avocados, no germination took place from fruit held longer than 20 days at a temperature of 32° F.

EFFECT OF COLD STORAGE UPON MEDITERRANEAN FRUIT FLY.

In 1907 some experiments were made in Australia* in which it was found that fruit fly maggots would resist temperatures from 44 to 38° F., but that at 33 to 35° F. eggs, after a short period of retention in cold storage, appeared fresh, but ultimately shriveled and failed to hatch after removal from cold storage. The maggots and eggs of fruit flies were found to live for 15 days at 33 to 35° F. In the beginning of the cold storage experiments reported in this bulletin some infested star apples were removed after 10 days in cold storage at 32° F., and placed in breeding jars. The maggots at the time of removal from cold storage were full grown and of normal color, but limp and apparently dead. No pupae developed, and no adult flies were recovered from this material. Similarly with figs removed after 10 days from refrigeration at 32° F., no adult flies could be bred from this material.

In order to test the effect of cold storage upon fruit flies in a more systematic manner a quantity of infested mangos and citrus fruits were picked and placed in the 32° and 36° F. rooms. Three fruits each of mangos and citrus fruit were placed in 13 baskets in each room. Each basket contained three mangos and three citrus fruits. One basket was removed from each room after an exposure of two and a half days, and one basket from each room thereafter for each day until a period of 15½ days had elapsed. The fruit upon removal from cold storage was placed in glass jars containing about 2 inches of moistened sand and covered with muslin. On the fourteenth day after removal from cold storage one adult fly emerged from the fruit which had been held 2½ days at 36° F. The next day three flies emerged from the fruit which had been held 2½ days at 32° F. Nine days later four flies emerged from the fruit which had been held 3½ days in cold storage at 36° F., and two flies from fruit which had been in cold storage 4½ days at the same temperature. Adult flies continued to emerge from the fruit which had been in cold storage 2½ days at 36° F., until in all,

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* Jour. Dept. Agr. West Aust. 15 (1907) p. p. 252, 253.

30 flies appeared in that jar. Adult flies also continued to emerge from fruit which had been in cold storage 2½ days at 32° F., until the whole number was 25. From that time on no more adult flies emerged from any of the jars. In this test therefore no adult flies emerged from fruit which had been held at a temprature of 32° F. longer than 2½ days, and no flies emerged from fruit which had been held at a temperature of 36° F. longer than 4½ days.

All of the fruit in these jars was badly infested and contained large numbers of eggs and of half and full grown maggots when placed in cold storage. The fruit was not cut open or otherwise disturbed after removal from cold storage, but was merely held in the breeding jars in order to determine whether any of the maggots in the fruit would be able to complete their development.

At the same time with these experiments, four small glass jars containing moist sand in the bottom in which six full grown fruit fly larva had been placed were put in each of the two refrigeration rooms. One jar was removed from each room at the end of 4, 7, 11 and 14 days.

The following results were obtained from the test in the 32° F. room. In the jar removed after 4 days, all six larva were limp and motionless but not discolored. Two larva subsequently pupated, but no further development took place. All jars were given a final examination 22 days after removal from cold storage. The jar which had been held for 4 days at 32° F. contained 2 dead pupa and 4 dead larva. In the jar which was held 7 days in cold storage all the larva were dead and showed a brownish discoloration upon removal. The same findings were made in the jars removed after 11 and 14 days. No adult fruit flies emerged from any of the jars held at a temperature of 32° F.

From the jars placed in the 36° F. room the following results were obtained. The larvae were alive and one had pupated at the end of 4 days. From jar removed after 7 days two were dead and four alive. All larvae were dead in the jars removed after 11 and 14 days. In the jar removed after 4 days one adult fly appeared

15 days after removal. This was the only fly to emerge from any of the larvae held in sand in cold storage.

Avocados are perhaps the only commercial Hawaiian fruits subject to infestation with Mediterranean fruit fly for which there is a demand on the mainland. In the experiments just reported fruit fly larva and eggs failed to live through an exposure in cold storage even at 36° F. for longer than 4½ days. It is not safe, however, to assume 4½ days as an outside limit. It would seem safe to assert that infested fruit maintained for two weeks at a temperature of 32° F. could not possibly contain the living fruit fly in any stage. Avocados, however, may be held for at least two months in cold storage.

Dr. E. A. Back and Mr. C. E. Pemberton since May, 1913, have been making elaborate experiments with fruit flies in cold storage. Their results, soon to be published, will show all the conditions of cold storage which must be observed to render infested fruit safe.

PICKLING AVOCADOS IN SALT BRINE.

It has sometimes been asserted that avocados could be pickled in salt water in such manner as to destroy the fruit fly and make them safe for shipment to the mainland. In order to determine this matter a few tests were made at the same time with the cold storage tests. Ripe and green avocados were placed in salt water of various strengths from ¼ pound to 1 pound of salt per gallon, and left to stand at an ordinary room temperature in glass jars. At the end of one month the avocados were found to be all perfectly preserved. The color, texture and appearance were the same as when the fruit was placd in the salt water. No fermentation or decay had taken place. The fruits were then placed in fresh water to extract the salt in order to determine the flavor of the fruit thus preserved. It was found that the flavor was flat and disagreeable. It seems doubtful whether avocados can be preserved in salt water without losing much of the delicacy of their flavor.

NEW FREEDOM PRINT

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Hawaii Agricultural Experiment Station

HONOLULU

J. M. WESTGATE, Special Agent in Charge

PRESS BULLETIN NO. 48

Suppression of Weeds Among Pineapples by Arsenite of Soda Spray

BY F. G. KRAUSS,
Superintendent of Extension Work.

The Haiku region on the Island of Maui is noted for its large yields of fine pineapples. In years of good prices and normal rainfall the crop is a profitable one to grow. The season just closing, however, has been most disastrous because of prevailing low prices, bad roads caused by an unprecedented rainfall, and last but by no means least, an unusual growth of weeds which it has seemed almost impossible to bring under subjection.

Even in seasons of normal rainfall, which average about 75 inches per annum, the weed factor has always been an expensive item in the cost of producing pineapples. The usual contract price for weeding pineapple fields in this region is $2.50 per month per acre, or $30 per annum, for monthly weeding. At the present time, owing to the suspension of weeding during the excessive wet season, growers are paying $10 to $40 per acre to have their fields weeded, the average price being $20.

Under the conditions prevailing in the Haiku district, no sooner has a field been gone over than a new crop of weeds appears. In fact, the weeds are always present. It is a perennial fight to keep them under subjection. Under these conditions any practical methods of control will be welcomed, even if they help only partly to solve the problem.

It was with this view in mind that the writer began experimenting with arsenite of soda spray on his homestead last June.

Two lots of the arsenite of soda solution were made up for comparative test, one according to the formula recommended by the Hawaii Experiment Station*, and the other in accordance with work done among sugar cane by Mr. C. F. Eckardt at Olaa.

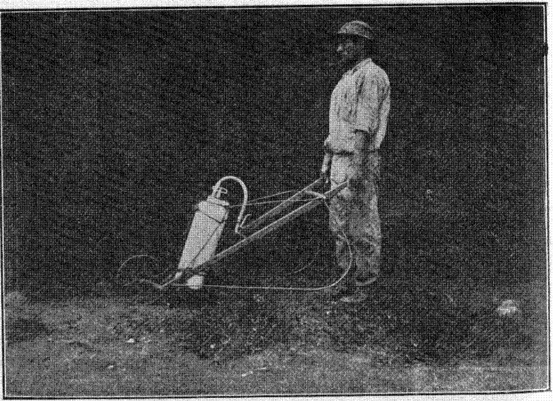

FIG. 1.—*Arsenite of Soda Sprayer, showing skeleton frame over which protective covering is placed.*

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*Hawaii Exp. Stat., Press Bull., No. 30, Killing Weeds with Arsenite of Soda.

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In the former formula 2 pounds of crystal sal soda and 1 pound arsenic is boiled in 1 gallon water until clear. "This stock solution is diluted in 24 gallons of water in the field and applied at the rate, roughly, of about 100 gallons of the dilute mixture per acre, more or less, according to the length and thickness of the growth."

This has been found effective on all the grasses and on the Hitchcock berry on the Nahiku Rubber Company's lands on Maui. The manager, Mr. W. A. Anderson reports that it has not been effective on "pualele (milk weed), ginger and wild taro. For best results on honohono a little stronger solution, perhaps one gallon of stock mixture to 20 of water, is necessary." Further on Mr. Anderson says: "Hilo grass is actually disappearing from our fields that have been plowed, and thereafter, treated with the spray, considerable areas are free from it; it has been thinned out everywhere."

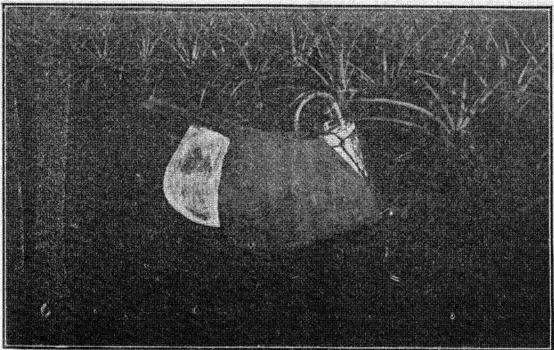

FIG. 2.—*Arsenite of Soda Sprayer, with canvas guard to protect pineapple plants.*

Our experience with this spray has been fairly effective. With us it quite effectively destroyed the young pualele, upon which Mr. Anderson found it ineffective. The so-called water grass (*Kyllingia brevifolia*) which is one of the worst weeds the Haiku pineapple grower has to contend with, especially during wet seasons, was but slightly affected, as well as some other weeds, notably the honohono, but even these succumbed to a second or third spraying when all conditions, especially that of the weather, were favorable. It will be noted that Mr. Anderson's normal spray solution contains about 4 pounds arsenic per 100 gallons, but that he recommends about 5 pounds for best results on honohono. One hundred gallons of spray are usually used per acre.

The first spray used by Mr. Eckart on Olaa Sugar Plantation, Hawaii, is substantially the same as far as the amount of arsenic is concerned as that used by Mr. Anderson at Nahiku Rubber Plantation on Maui. Both regions are characterized by heavy rainfall. The Olaa stock solution consists of 20 pounds white arsenic, 4 to 5 pounds caustic soda, and 10 gallons water. This is boiled for 10 to 15 minutes. Two and a half gallons of this stock solution are diluted to 100 gallons with water. Thus it will be seen that 100 gallons contains 5 pounds arsenic. But only about 1 pound of caustic soda is used at Olaa against about 8 pounds crystal sal soda as used at Nahiku. Theoretically the caustic soda would be about three times as efficient as the sal soda.

In the experiments among pineapples at Haiku, both sprays gave substantially the same results, which were as noted above. However, the main drawback to both these sprays, especially where the excess of caustic soda was used, was the caustic effect of the soda upon the operator. Whenever the spray came in contact with the skin there was trouble. It was with a view to ameliorate this condition that the formula given below was finally adopted at the suggestion of Mr. L. D. Larsen, of the Hawaiian Sugar Planters'

Association, and used with the results as recorded further on.

In July the solution was made up according to the following formula, soda ash being substituted for the sal soda:

5 pounds white arsenic, at 7½ cents per pound	.37½
5 pounds soda ash (carb. of soda), at 7½ cts per pound	.37½
10 gallons water.	

This was boiled for about 15 minutes or until the solution was clear. It was then diluted with water to make 100 gallons of solution ready for use. This amount was applied over approximately an acre of weedy land having a large proportion of manienie and Hilo grass. The results were quite as effective as with the sprays used by Anderson and Eckart, if not more so, but this may have been apparent rather than real, as the weather conditions may have been more favorable in the latter experiment. The important thing is that the caustic quality of the new spray was greatly lessened, and in this must lay its main advantage. However, there may also be a slight saving in the cost of using the soda ash in place of the caustic soda or the sal soda.

The former costs 3½ cents per pound, while the sal soda and soda ash cost about 2½ cents per pound at wholesale. Theoretically the soda ash is two or three times as efficient in combining with the arsenic as is the sal soda.

While the use of 5 pounds of arsenic per 100 gallons of water applied per acre was fairly efficient in destroying or at least suppressing most of the weeds encountered, the water grass (*Kyllingia brevifolia*) as well as the honohono were not materially affected. A second spraying within a week of the first application increased the suppression considerably. This suggested that doubling the strength of the solution might save spraying the weeds twice. Accordingly, in October, 10 pounds of arsenic and 5 pounds of soda ash were used to make up 100 gallons of solution. This has been very effectively applied to the following weeds: Pualele or sow thistle (*Sonchus oberaceus*) Rattle pod (*Crota-*

laria longirostrata), White wood (*Crotolaria var.*) Pig weed or purslane (*Portulaca oleracea*), Honohono (*Commelina nudiflora*), Manienie or Bermuda grass (*Cynodon dactylon*), Hilo grass (*Paspalum conjugatum*), Water grass (*Kyllingia brevifolia*) and the common guava.

These weeds were affected in about the order named. When young, say from three to six inches tall, most of the weeds turn brown in from two to three days, the young pualele usually wilts within ten to twenty hours after spraying, especially when the weather is bright and warm. Should it rain within 12 hours ot spraying the effect may be nil or nearly so on all but the most tender weeds. When the weeds were nearly mature, it required fully four days before the full results were accomplished. While the honohono, water grass, and guava were not wholly destroyed in any case, they were suppressed to an extent that proved of great economic value.

Naturally, the spray affects all plant life with which it comes in contact. The pineapple is apparently unusually susceptible to the effects of the arsenite of soda, and it was soon found that every precaution must be taken to avoid contact.

The contrivance shown in figures 1 and 2 has proved highly efficient for the purpose intended. The spray tank used is of the well-known compressed air type, and has a capacity of three gallons liquid and one of air. This is lashed between the handles of a single wheel hoe, the tank resting securely on the iron frame to which are normally attached the weeding implements that go with this machine. On the outside of both handles, near the wheel, there is attached a light but strong iron rod which runs along the surface of the ground towards the operator until it reaches a point about where the operator's legs would be while walking. It then turns up to the handle bars. This forms a wedge shaped frame which parts the pineapple leaves, and when the frame is covered with light oiled canvas, provides a very effective guard against any of the spray reaching the leaves or stems of the plants. The total cost of this outfit is not more than $15. The "Auto Sprayer" which was used in this instance cost $8.50. The single wheel frame $2.50, and the labor and material for assembling, about $2.50 more.

An active man can easily cover 2 acres per day of 10 hours among pineapples in rows planted 48 inches apart. This includes filling the tank from 50 to 60 or 70 times.

A larger tank, say one of 6 to 10 gallons capacity, would doubtless greatly increase the efficiency of the outfit and the writer has now under way the construction of a 10 gallon tank to fit into the triangular space between the handle bars of the same frame as shown in the figures. Any good spray nozzle which can readily be turned on and off will answer the purpose. It was found necessary, however, to redrill the aperture to a size and angle that will most effectively cause the spray to cover the area between the rows of pineapples under treatment. In the experiments thus far conducted between two-thirds and three-fourths of the space between the rows was successfully treated.

Weeding contractors have already offered to weed fields that have been sprayed, for half the amount asked on unsprayed areas. As the writer is now paying $10 to $20 per acre to have his pineapples weeded, the spraying will effect a saving of from $5 to $10 per acre less the cost of spraying.

The cost of spraying per acre as now practiced is about as follows:

Labor of spraying 1 acre of pineapples (½ day at $1.50)	$ .75
100 gallons spray solution:—	(max.)
5 to 10 pounds arsenic at 7½ cents....................	.75
2½ to 5 pounds soda ash at 7½ cents	.37½
Cost of preparing solution	.25
Spraying outfit, interest and deterioration	.17½
Total cost of spraying 1 acre	$2.30

The materials used in the spray can be bought, at wholesale, for about one-third the prices given above, thus effecting a large saving. It is suggested that the pineapple growers of a district get together and buy their materials in original packages at wholesale.

It should be remembered that this method of weed suppression is comparatively new. In so far as the writer is aware, arsenite of soda spray has not been used among pineapples except in the demonstrations here reported. It is, therefore, not yet known what may be the effects of accumulated arsenic upon pines growing under conditions where the weeds are repeatedly sprayed. A word of warning is, therefore, given to operators to look carefully for signs of any possible injury that might result from the repeated use of arsenic spray among pineapples.

Issued Jan. 18, 1915

Hawaii Agricultural Experiment Station

HONOLULU

J. M. WESTGATE, Special Agent in Charge

PRESS BULLETIN NO. 49

A Cheap and Effective Home-made Plank Drag

By F. G. KRAUSS,
Superintendent of Extension Work.

INTRODUCTION.

The plank-drag or "Clod masher" as it is sometimes aptly called, is doubtless, next to the plow and harrow, the most efficient implement that can be used in fitting the seed bed for immediate use. For the purposes for which it is particularly intended, no other implement will take its place. Yet this simple contrivance, which is used on nearly every farm on the mainland, is comparatively unknown in Hawaiian agriculture.

USE OF THE PLANK-DRAG.

When land breaks up "cloddy" from whatever cause, conditions are often such that no amount of harrowing with spike tooth, disc, Acme or any other kind of harrow will pulverize the soil. Especially is this the case when the soil becomes hard and dry. It is at this stage of tillage that the plank-drag becomes invaluable. Unless the land is too moist, the plank-drag should follow the harrow immediately. This will increase its efficiency materially by reason of the freshly turned up clods pulverizing much more easily than when exposed to the sun and drying winds, which bake and harden the clods until it becomes almost impossible to demolish them by any ordinary means.

In going over the ground with the drag a half lap should always be taken, and if necessary, the ground should be cross dragged. The drier and harder the clods the greater should be the weight applied. A 4 x 8 foot drag made of two inch planks weighs about 250 pounds. If the driver "rides" considerable weight will be added. However, it is sometimes advisable to add a boulder or two to give the necessary weight to crush large hard clods. Care should be taken not to add too much weight when the soil is moist since in so doing the soil may become compacted to an extent far greater than any beneficial results that might otherwise have accrued. The drag shown in the illustration, Fig. 1, is 40 by 96 inches in size including 2 inch lap of planks. It is easily handled by two medium size horses. Four to six acres a day can readily be covered when giving half a lap, which is virtually going over the ground twice.

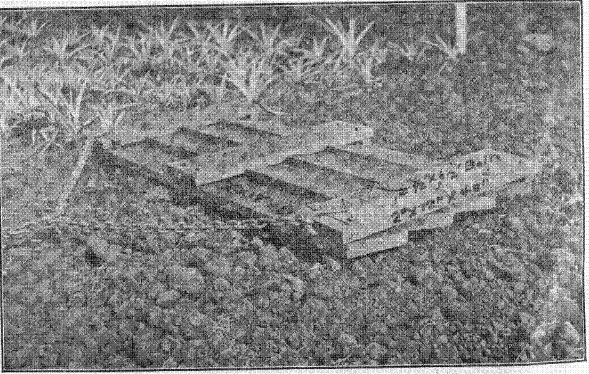

Fig. 1. Plank Drag, showing details of construction.

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CONSTRUCTION OF THE PLANK DRAG.

Tough, hardwood planks are of course the most durable material to use for making the drag, but the writer has found 2 inch plank of the common northwest pine quite satisfactory. This timber is cheap and is easily worked. With ordinary use a pine drag will last two or three seasons. If the edges of the projecting plank are protected with flat strips of iron, or angle iron, which is better still, and the whole is well bolted, the drag may last from five to ten years.

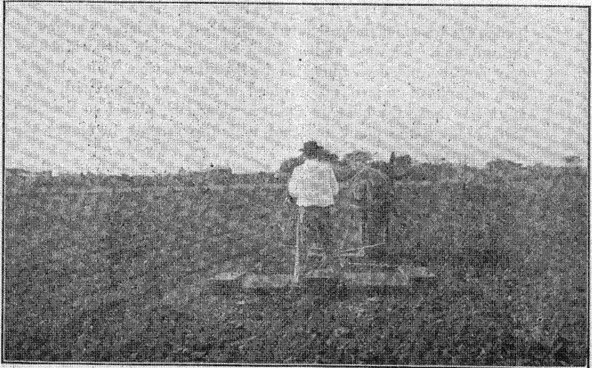

Fig. 2. Plank Drag in use.

The writer has had three years of the hardest kind of usage out of an "unshod" 2 inch pine drag but believes it would be economy to face the edges of the plank with iron.

The following directions should enable any farmer to make a first class drag in less than half a day, and at a cost not exceeding $3 for material, Honolulu prices.

Select four pieces good tough pine or other timber, eight feet long, twelve inches wide and two inches thick. Lay these out on a level surface, letting each plank lap two inches along its

entire length as shown in the illustration. Hold in this position by driving a few spikes along the lapped edges. Now cut three pieces of the same kind of plank into forty inch lengths for cross pieces. These are best "let in" an inch or so, as shown in the end view of Figure 1. This greatly increases the rigidity of the whole structure. This is easily done by laying the cross pieces in place and using them as a guide for the saw. When the projecting edges of the plank have been sawed into an inch or two, the obstruction is quickly chiselled out and the cross pieces set in. Pin down with a couple of spikes and then bore holes to receive one half inch bolts as indicated in the illustration. Carriage bolts ½ x 6½ inches are best and these should be supplied with large washers at the nut end. Clevises and a chain for attaching the whiffletree may now be added as indicated in the illustration. The drag is then completed unless it is decided to face the edges with iron. If this is done, the holes in the iron should be placed so that the bolts holding the plank together will also answer to secure the iron strips.

The following material will be needed to make a drag such as is outlined above:

4 pieces 2″ x 12″ x 8′
3 " 2″ x 12″ x 40″
30 carriage bolts ½″ x 6½″
30 iron washers.

The iron strips for facing the edges of the planks may be made from old wagon tires. A chain and clevises can usually be found about the place, but if it is necessary to purchase everything that has to enter into the complete drag the cost will be about $5.

Figure 2 shows the drag in use as a clod masher, leveler and smoother, making ready the land for marking off for corn.

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Issued June 10, 1915

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Hawaii Agricultural Experiment Station

HONOLULU

J. M. WESTGATE, Agronomist in Charge

PRESS BULLETIN No. 50*

The Effect of Arsenite of Soda on the Soil

By W. T. McGeorge,
Chemist.

Introduction

The use of poisonous chemicals as a means of destroying weeds, while not a new idea, until comparatively recent years found little application in Hawaiian agriculture. About five years ago this Station carried on experiments[1] with various chemicals, the results of which indicated sodium arsenite to be a very effective and economical weed destroyer.

At the present time this means of controlling weed growth has long since passed the experimental stage and is now quite widely applied. Especially is it applicable in the rainy sections where the growth of weeds is profuse and cultivation is often impossible without puddling the soil.

Considerable credit is due Mr. W. A. Anderson, Manager of the Nahiku Rubber Co. for the first successful application of this chemical on a large scale in these islands. On large areas on the rubber plantations plowing has been entirely replaced by the arsenical spray in the last five years. A further extensive test has been made by the Parker Ranch as a means of eradicating such weeds as thimble berry and German ivy from their pasture lands. Since these successful applications the use of this spray has increased until it has entirely replaced hoeing on some plantations and partially replaced plowing, even in the dry sections.

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*Note.—This Bulletin, as well as Press Bulletin No. 48, entitled "Suppression of Weeds Among Pineapples by Arsenite of Soda Spray," and Press Bulletin No. 49, entitled "A Cheap and Effective Home-made Plank Drag," was prepared under the direction of Dr. E. V. Wilcox, Special Agent in Charge, previous to Jan. 1, 1915.

OBJECT OF THE WORK

The status of arsenite of soda as a weed destroyer is firmly fixed, from both a practical and an economical standpoint. But there still remains to be considered the effect of this chemical upon the soil and the growth of plants. Comparatively little work of this nature has been done but it is quite generally conceded that plant growth is materially affected by the presence in the soil of this chemical. The Colorado Experiment Station[2] has made some investigations upon the death of fruit trees excessively sprayed with insoluble arsenical compounds, and the Bureau of Chemistry of the U. S. Department of Agriculture[3] has investigated the death of plants as a result of arsenic settling from smelter fumes. In all cases arsenic has been found in both the soil and the plants in appreciable amounts.

In view of the above facts and the increase in use of arsenite of soda in the Hawaiian islands, the Station undertook an exhaustive study of the effect of this chemical upon plant growth and its physical, chemical and biological activities in the soil. While no deleterious effects have appeared through its use thus far, yet it is highly essential that we should be able to recognize them immediately should they appear.

PREPARATION OF THE SPRAY.

Several formulas have been recommended for the preparation of this spray. They all involve the boiling of white arsenic with sal soda or caustic soda, the two being added in sufficient quantities to combine, forming soluble sodium arsenite. When thus boiled there are two salts of sodium arsenite possible of formation the acid salt ($Na_2O.\ 2\ As_2O_3\ 2\ H_2O$) and the neutral salt ($Na_2O.\ As_2O_3$). Therefore the resulting compound depends upon the proportion of the two ingredients. The following equations illustrate:

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$$\text{(1) } Na_2CO_3\ .10H_2O + As_2O_3 = Na_2O.\ As_2O_3 + CO_2 + 10H_2O$$
$$\text{(2) } 2NaOH + As_2O_3 = Na_2O.\ As_2O_3 + H_2O$$
$$\text{(3) } Na_2CO_3\ .10H_2O + 2As_2O_3 = Na_2O\ .2As_2O_3 + CO_2 + 10H_2O$$
$$\text{(4) } 2NaOH + 2As_2O_3 = Na_2O\ .2As_3O_3 + H_2O$$

Equations 1 and 2 represent proportions for the formation of the neutral salt. By calculating from these two relationships it appears that it will require approximately 1.5 pounds sal soda or only 0.4 of a pound of caustic soda to react with 1 pound of white arsenic to form neutral sodium arsenite. Equations 3 and 4 represent the proportions at which the two react to form the acid salt. From these it can be shown that approximately 1 pound of sal soda combines with 1½ pounds of arsenic, and 1 pound of caustic soda combines with 5 pounds of arsenic to form the acid salt.

The effectiveness of the two salts as weed destroyers is very much the same. However, from an economical standpoint the neutral salt which has given excellent results upon most weeds is as follows[4]:

2 pounds sal soda
1 pound arsenic
1 gallon water.

Boil this mixture until clear, then dilute to about 24 gallons for spraying. Instead of 2 pounds sal soda, 7 ounces of caustic soda will produce the same results. However, the use of the latter salt involves a certain degree of danger to the laborers who may be required to handle it while the sal soda is practically harmless.

On Olaa plantation where the use of poisonous sprays has been given a thorough test the acid sodium arsenite is in use. The following formula has been adopted and is very effective:

20 pounds arsenic
4 to 5 pounds caustic soda
10 gallons water.

This mixture is boiled for 10 to 15 minutes and the whole diluted to 400 gallons. Instead of 4 pounds caustic soda approximately 13 pounds sal soda would be required.

Effect on plant growth.

In order to gain some information with reference to the effect of arsenite of soda upon plant growth a series of pot experiments was carried out. For these experiments three soils were used and three crops. The soils included the heavy red clay type No. 1; a brown clay type No. 2; and a highly organic silt, No. 3. The soils were also of different chemical types and partial analyses are herewith inserted for reference:

ANALYSES OF SOILS USED.

Soil	Insol. matter per cent	Iron Oxide per cent	Alum. Oxide per cent	Lime per cent	Magnes. per cent	Potash per cent	Phos. Acid per cent	Vol. and Organic Matter per cent	Moisture per cent
1	33.17	21.08	17.70	.88	1.01	.16	.68	12.65	8.67
2	35.37	35.40*		.82	6.24	1.34	.35	11.55	7.36
3	32.69	10.13	12.59	2.63	1.09	.14	1.02	13.08	25.46

The crops used were millet, cowpeas and buckwheat, all of which have been found to give excellent growth in pots. Neutral sodium arsenite was applied to the pots in varying amounts as shown in the following table:

EFFECT OF ARSENIC ON PLANT GROWTH.

BUCKWHEAT

Pot	Arsenic in soil per cent.	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants
1	.011	15.0	5	16.0	5	44.6	5
2	.005	7.2	5	16.4	5	45.5	5
3	.010	12.8	5	18.7	5	51.0	5
4	.015	8.3	4	15.0	5	49.3	5
5	.050	..	..	8.5*	3	14.8	3
6	.100	..	..	11.6*	5	..	..
7	.250	..	..	..	..	..	..
8	check	22.0	5	13.8	5	45.3	5

COWPEAS.

Pot	Arsenic in soil per cent.	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants
1	.001	82.5	4	161.0	4	206.5	5
2	.005	65.0	4	61.0	2	107.0	2
3	.010	40.0	4	92.0	1	..	..
4	.015	49.0	4	114.0*	5	22.0	1
5	.050	12.2*	4	39.0*	2	14.0*	1
6	.100	..	..	..	..	..	..
7	.250	..	..	..	..	..	..
8	check	51.5	4	129.5	3	202.0	5

MILLET

Pot	Arsenic in soil per cent.	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants	Wt. of air dry plants gms.	No. of plants
1	.001	14.5	5	23.5	5	73.0	5
2	.005	8.2	5	20.5	5	26.5	5
3	.010	6.0	5	19.5	5	69.5	5
4	.015	7.2	5	31.7	5	68.0	5
5	.050	..	..	16.5*	5	20.5*	5
6	.100	..	..	..	..	..	..
7	.250	..	..	..	..	..	..
8	check	10.0	5	25.0	4	64.2	4

*Represents weight of second planting, the first having died.

In some of the pots the seed germinated but the plants soon turned brown and died. All pots in which plants died at first planting were replanted and in several instances the seeds germinated at second planting and though much stunted in growth reached maturity.

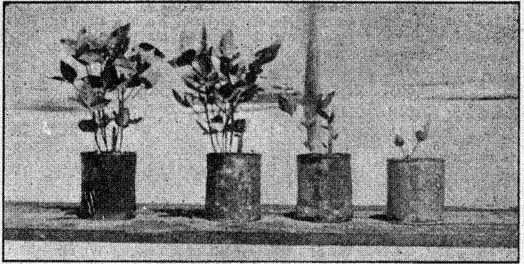

Fig. 1—Cowpeas—Soil No. 3
From left to right, Pots No. 8, 1, 2, 4.

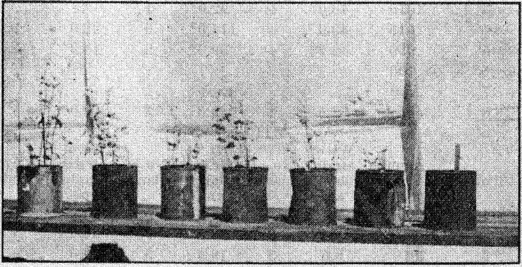

Fig. 2—Buckwheat—Soil No. 1
From left to right, Pots No. 8, 1, 2, 3, 4, 5.

These plants indicate strongly that the effect of sodium arsenite on plant growth depends upon the resisting power of the plant and upon the chemical and physical nature of the soil. It might be said that in small quantities the plant growth is stimulated in most instances, but when added at the rate of .10 to .25 per cent, plant growth is practically impossible. No fertilizers were added to these pots and it is highly probable that their addition might influence the action of he arsenic.

The accompanying plate (Figs. 1, 2 and 3) illustrates more clearly the effect of this chemical. All photographs were taken when the plants were about 1 month old, and some of the most stunted plants died before reaching maturity.

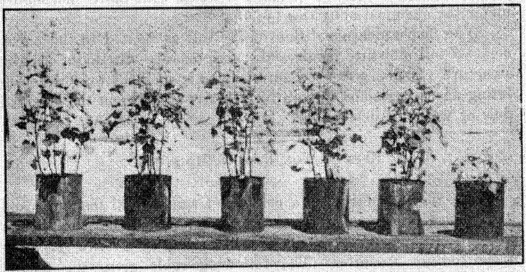

Fig. 3—Buckwheat—Soil No. 3
From left to right, pots No. 8, 1, 2,3, 4, 5.

Arsenic determinations were made on all plants from pots numbered 4, 5 and 6. The Marsh apparatus was used in the analysis as described in U. S. Dept of Agr., Bur. of Chem., Bul. 113, p. 61. It was found to be present in all plants grown in these pots, but not in weighable amounts, working on a 5 gram sample, except pots No. 5, millet and buckwheat grown on soil No. 3. In the former case it amounted to .0018 per cent and in the latter .0053 per cent. This indicates that the arsenic passes from the soil into the plant tissues and that when present in the plant in minute quantities growth is materially stunted.

EFFECT UPON THE PHYSICAL CONDITION OF THE SOIL.

One of the most noticeable effects of sodium arsenite in the pot experiments was its action upon the physical condition of the soil. It has a very strong deflocculating action which may be attributed to either one or both of two reasons. First, arsenious acid belongs to the class of weak acids such as phosphoric and others, the alkali salts of which have a strong deflocculating effect upon clay. Second, when sodium arsenite is added to the soil, a process known as selective absorption takes place, setting free the soda. This phase of the question is dealt with more thoroughly under the chemical activities (p. 13).

The mechanical condition of the soil as related to the movement of soil moisture involves the maintenance of a loose crumby structure. Hence, since sodium arsenite is such a strong deflocculating agent it seemed imperative that its effect upon the rise and flow of water be determined.

EFFECT UPON RISE OF MOISTURE.

For these experiments a column of soil several feet long and 1 inch in diameter was used, the bottom of the column standing in a solution containing 200 parts per million of arsenic (As_2O_3) from sodium arsenite. The following table gives the results obtained:

	Soil No. 1		Soil No. 2		Soil No. 3	
Time	Blank cm.	Arsenic cm.	Blank cm.	Arsenic cm.	Blank cm.	Arsenic cm.
1 hr	16.0	15.1	15.9	16.5	22.4	21.4
3 ”	20.6	19.8	22.3	22.5	34.8	33.5
7 ”	24.0	23.6	28.8	27.2	46.0	44.0
22 ”	29.1	28.9	37.0	34.7	60.8	58.4
46 ”	33.4	33.8	44.1	38.5	69.7	67.4
68 ”	35.8	36.4	49.1	41.7	75.4	72.7
72 ”	37.6	38.5	52.4	44.5	79.3	76.5
116 ”	39.4	40.2	57.6	49.7	86.2	83.2
164 ”	41.8	42.7			90.7	87.7

These results show the rise of water to be diminished in two soils and practically unaffected in the third.

In the next table are given data showing the effect upon the flow of water through the soil. The apparatus used was very similar to that described above except that the soil column was kept under a constant head of one inch of a solution containing 200 parts per million arsenic. The amount passing through was measured at various intervals.

EFFECT OF ARSENIC ON PERCOLATION OF WATER THROUGH SOILS.

	Soil No. 1		Soil No. 2		Soil No. 3	
Time	Blank	Arsenic	Blank	Arsenic	Blank	Arsenic
	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
8 hrs	286	416	78	183	134	128
24 ”	695	650	90	94	225	164
32 ”	365	230	35	18	119	38
48 ”	910	680	67	18	236	37
56 ”	400	305	28	..	..	..
72 ”	770	420	40	18	37	6
80 ”	420	135	..	..	..	..
98 ”	620	240	44	14	..	..
112 ”	950	..	..	..	..	..

Thus it may be seen that the deflocculating action of this chemical is directly related to the movement of water. It causes the soil particles to swell, more especially in the organic soils and as the concentration increases a water logged condition ensues. It also accentuates the colloidal state thus increasing the friction and thereby making the passage of water more difficult.

Biological Influences.

Arsenic belongs to the class of chemicals known as very strong poisons. All forms of plant and animal life are influenced by these chemicals, the degree of effectiveness depending on the amount of arsenic present and the degree of resistance exhibited by the plant or animal. Among the most important lower plants within the soil are the bacteria which ammonify and nitrify the nitrogenous material, thus rendering the inert componds of this element available to the plants. The rate of ammonification or nitrification is even greatly influenced by the presence in the soil of excessive amounts of salts generally considered comparatively inert[5]. Thus their development and functions would be expected to be greatly influenced by the presence of such a virulent poison as arsenic.

AMMONIFICATION.

For determining the influence of arsenic toward the organisms which bring about ammonification the following method was used. One hundred grams of soil and 1 gram of dried blood were weighed into glass tumblers, arsenite of soda added in varying amounts, the moisture content brought up to the optimum point and the whole well stirred. They were then incubated for 7 days and the ammonia determined by the usual method. Results are given in the following table:

EFFECT OF ARSENIC ON AMMONIFICATION.

Arsenic in soil per cent.	Soil No. 1 Ammonia in 100 gms. soil mgs.	Soil No. 2 Ammonia in 100 gms. soil mg.	Soil No. 3 Ammonia in 100 gms. soil mg.
.001	35.5	98.4	40.5
.005	21.3	75.3	43.0
.010	27.8	83.3	51.5
.015	35.1	76.1	48.0
.050	28.5	71,4	70.4
.100	33.0	81.2	90.0
.250	34.0	76.0	100.1
.500	..	..	85.8
1.000	..	..	99.1
Check	34.5	87.1	53.7

From the above results it may be seen that in some proportions a stimulation takes place while in others a retarding influence is noted. No general law is applicable to all soils. The greatest stimulation is noted in the organic soil (No. 3), being at .25 per cent As_2O_3 almost double that of the check. A strong stimulation is also apparent even at the excessive content of one per cent. The least stimulation is to be found in the soil of heaviest clay content. Hence an obvious conclusion to be reached from these results is that the influence of sodium arsenite on ammonification depends primarily upon the mechanical composition of the soil and possibly to some extent upon the presence or absence of organic matter.

NITRIFICATION.

In order to study the influence upon the nitrifying bacteria, the same method described under the determination of the ammonifying power was used except that the incubation extended over a period of 21 days. The per cent nitrates in the soil was then determined by the usual method. The results are given in the following table.

EFFECT OF ARSENIC ON NITIFRICATION.

Arsenic in soil	Soil No. 1 Nitrogen As NO_3	Soil No. 2 Nitrogen as NO_3	Soil No. 3 Nitrogen as NO_3
percent.	p.p.m.	p.p.m.	p.p.m.
.001	82	310	455
.005	114	280	350
.010	240	275	350
.015	66	275	320
.050	400	210	330
.100	88	260	375
.250	24	260	405
Check	80	300	370

The influence of sodium arsenite on the nitrifying bacteria was greatest in the red clay soil (No. 1). Here there was a decided stimulation up to .05 per cent, followed by a rapid reduction in nitrate content. In the other soils the influence was less marked. In these the functions of the bacteria were apparently little influenced even by excessive amounts of the arsenic. In soils 1 and 3 there was little correlation in the influence upon the ammonifying and nitrifying bacteria while in soil No. 2 the action was very similar.

CHEMICAL ACTIVITIES.

When any chemical salt is added to a soil it either combines with or replaces substances already present or remains inactive and is readily washed out by the rains. Still other salts are broken up or decomposed after being added to the soil, one part being washed out while the other remains fixed. This process is known as selective absorption. Most salts belong to the first or second class and it is of the greatest importance that we know whether arsenic remains fixed in the soil or is washed out by the rains. If it is inactive then it may be considered harmless but if active toward substances already present then a judicious use is imperative.

The first series of experiments to determine the action of arsenic upon the soil from a chemical view point, were made with the use of large glass percolators, 800 grams of soil being placed in each of six percolators. The soils used were the same three as used in the pot experiments. In this case 500 cc of a solution of sodium arsenite containing 184 parts per million arsenic was poured into the percolator every day for 3 days and the analysis of the filtrate made to determine how much arsenic had been taken out by the soil. These simple tests indicated a strong affinity of soils for arsenic, the first portions of the filtrate being absolutely free of this chemical. Later portions passing the soil contained slight traces.

In view of the above results a more thorough test was made upon these same soils with lysimeters, using about 25 pounds of soil. A solution of sodium arsenite of the same strength as used in spraying was prepared and about 3 litres (approximately 3 quarts) poured on the soil in each lysimeter. Two lysimeters were filled with each soil, to one of which the 3 litres of arsenic spray was applied and the lysimeter allowed to stand about 2 months. Samples of the soil were then taken at different depths to determine how deep the arsenic had penetrated and to what extent it had distributed itself at various depths. To the second lysimeter one quart of water was added every other day for several weeks, then allowed to remain until dry enough to sample. Samples were then taken at different depths to determine to what extent the arsenic is carried down by the movement of the water.

ARSENIC (As_2O_3) AT DIFFERENT DEPTHS IN SOIL IN LYSIMETERS.

	Soil No. 1		Soil No. 2			Soil No.3	
Depth	Not leached	Leached	Not leached	Leached	Depth	Not leached	Leached
	p. cent.	p. cent.	p. cent.	p. cent.		p. cent.	p. cent.
1-3 in.	.280	.224	.450	.237	1-2 in.	.97	.95
3-5 in.	.198	.211	.170	.092	2-4 in.	.50	.47
5-7 in.	.171	.145	.118	.092	4-6 in.	.00	.00
7-9 in.	.184	.170	.013				

In the above table the first column represents the depths to which samples were taken from soils 1 and 2. Soil No. 3 was sampled at different depths as indicated in column 6. Apparently the organic matter is most active toward arsenic as in the highly organic soil (No. 3) it was practically impossible to wash out the arsenic. These data show the extent to which arsenic is held in the soil by absorption and indicate the danger to be expected from the accumulation of excessive applications.

The tract of land which has been sprayed longest in these islands is at Nahiku. Here the weeds have been kept down for the last 5 years by three sprayings per year at the rate of 5 pounds per acre per application. No plowing has been done and hence the soil has remained undisturbed. During this time the rainfall has amounted to about 200 inches per year, and the soil during this time has been subjected to heavy washing. A large percentage of the water has penetrated into the soil as the loss of water through surface washing is very low in this district. Through the kindness of Mr. Anderson samples were obtained from this district to a depth of 12 inches, being taken every 4 inches. The first 4 inches contained .00924 per cent arsenic (As_2O_3), the samples below this depth contained none at all. This is entirely in accord with the results obtained in the lysimeters.

The nature of the reaction between the sodium arsenite and the soil is apparently one of complex proportions. The greatest activity is with the iron and humus and to a less extent the lime and magnesia. A complete analysis of the filtrate collected from the percolation experiments, using a solution containing 200 parts per million arsenic, disclosed very little conclusive data. However, the concentration was, in most instances, found to be greatest in the filtrates obtained by passing the solution of sodium arsenite through the soil as compared with a water extract.

In order to magnify the action of sodium arsenite a series of experiments was planned as follows: 200 grams each of the 3 types of soil was weighed into a large bottle and to this was added 1 litre of a solution containing 1 per cent sodium arsenite. Check experiments were also made upon the soils using 1 litre of water. These were well shaken at intervals for several days and allowed to stand two weeks. They were then filtered and analyses made on the filtrates, and humus determined in the soils.

The following table shows the percent of humus removed from the soil by treatment with sodium arsenite.

HUMUS REMOVED FROM THE SOILS BY TREATMENT WITH 1 PER CENT. SODIUM ARSENITE SOLUTION.

Soil Number	Humus in soil. per cent.	Humus in soil after treatment per cent.	Humus dissolved. per cent.
1	2.77	1.56	1.21
2	1.68	1.80	0.00
3	8.75	8.40	0.35

In the next table is presented data relating to the changes in composition of the sodium arsenite solution when in contact with the soil.

ANALYSES OF WATER AND ARSENIC EXTRACTS OF SOILS.

	Soil No. 1		Soil No. 2		Soil No. 3	
	Water extract mg.	Arsenic extract mg.	Water extract mg.	Arsenic extract mg.	Water extract mg.	Arsenic extract mg.
Iron oxide	trace	716.0	trace	121.0	trace	90.0
Calcium oxide ...	11.2	84.0	13.6	124.0	74.6	126.
Magnesium oxide	3.6	20.0	10.8	44.0	7.4	26.0
Arsenic (As_2O_3)..	..	396.0	..	6000	..	4480.0
Arsenic fixed by 200 gms. soil..	..	2640	..	600	..	2120.0

The above figures represent miligrams per litre, excepting the last column which gives miligrams of arsenic (As_2O_3) fixed by the soil. An analysis of the solution used shows an arsenic content of 6600 miligrams per litre.

From these data it is possible to advance several theories as to the action of this chemical. The soluble action toward humus is undoubtedly a result of selective absorption. That is, the arsenic is absorbed and the soda liberated as the carbonate or possibly hydrate. The action of sodium carbonate toward humus is well known, it being responsible for the black alkali lands of the western states. The supposedly neutral salt of sodium arsenite is alkaline in reaction and as long as it is in solution in contact with the soil it remains alkaline, at least in so far as these experiments were carried out. But soon after filtering the soil the solution becomes acid or neutral or possibly may remain alkaline depending on the degree of absorption which took place when in contact with the soil.

As additional proof of the theory that selective absorption takes place it should be stated that the soil absorbing the highest weight of arsenic was in contact with the solution of highest alkalinity and lost, through solution, the most humus. The soil absorbing the least arsenic lost no humus.

The extract of the soil treated with arsenic was very dark in color according to the humus dissolved. On acidifying this extract with hydrochloric acid a large per cent of the humus was precipitated, carrying with it a large percentage of the iron. This is a well known property of humus as extracted from soils by ammonia.

The most striking figures are those showing the increase in solubility of iron as effected through the presence of sodium arsenite. The solubility of this constituent of our soils is very low. It is present in a form soluble in water, in only minute traces.

The interaction of the arsenic and iron apparently depends upon the form in which the latter exists in the soil. Soil No. 1 is a red clay and here the reaction is strongest, soils number 2 and 3 are a brown and a black soil respectively and the action is far less marked. What the nature of the action is it is impossible at this time to say as it would involve the establishing of the presence or absence of ferrates or ferrites in the soils. This involves an investigation too technical for a bulletin of this sort. Further work of this nature is contemplated. The reaction with the red soil is primarily chemical, the arsenic replacing the iron and the latter going into solution. It is first necessary to determine definitely the chemical form in which the iron exists in the soil in order to present a theory as to the nature of the reaction.

The preceding table shows the red soil to have absorbed the most arsenic, while the results in the lysimeters show the organic soil to have the highest absorbing power. This is due to the fact that the arsenic solution acts more slowly upon the physical properties of the red soil and hence in the lysimeters penetrates to a greater depth before fixation is complete. Further proof of this may be had by reference to the tables showing effect on capillary rise and fall of water. The movement in the red soil is influenced least by the arsenic.

SUMMARY.

1. Arsenite of soda has been used as a spray for killing weeds in Hawaii for about five years.
2. As a means of eradicating these pests it has proved cheap and effective.
3. Two formulas may be used in preparing the spray. One results in a neutral sodium arsenite, the other in an acid sodium arsenite. The former is the more economical, adds less arsenic to the soil, and is equally efficient as a weed destroyer.
4. Plant growth is very sensitive to this poison, the resistance varying with the different plants and the different types of soil. It is assimilated by the plant and on analysis of the dead plants may be found scattered throughout the tissues.
5. The mechanical condition of the soil is materially altered by its presence. Its action is primarily that of a deflocculating agent, thus checking the movement of the water.
6. The influence upon the soil bacteria varies considerably in the different types of soil and no general rule seems to apply within reasonable limits.
7. This chemical is strongly fixed by the soil even resisting the washing of excessive rains, and is shown to accumulate in the top layer. A sample of soil taken from a tract of land sprayed for five years, on analysis showed all the arsenic to be present in the top four inches of soil.

While there is no immediate danger from the use of arsenite of soda in killing weeds it is imperative that it should not be used in excessive amounts if, as these experiments indicate, the accumulation in the top few inches of the soil is to continue indefinitely.

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[1] Press Bul. 30, Haw. Exp. Sta.
[2] Colorado Exp. Sta. Buls. 131 and 157.
[3] Bur. Chem. U. S. Dept. Agri., Bul. 39.
[4] Press Bul. 30, Haw. Exp. Sta.
[5] Biochem. Bul. 3 (1913), pp. 2-16.

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Hawaii Agricultural Experiment Station
HONOLULU

J. M. WESTGATE, Agronomist in Charge.

PRESS BULLETIN No. 52.

Comparative Value of Legumes as Green Manures.

By MAXWELL O. JOHNSON,
Chemist,

ALICE R. THOMPSON,
Assistant Chemist,

and

C. A. SAHR,
Assistant Agronomist.

INTRODUCTION.

For many years, the Hawaii Agricultural Experiment Station has advised the growing of leguminous crops as green manures in every system of permanent agriculture under Hawaiian conditions. The value of green manures for practically every type of soil is well known, and for the heavy clay soils of Hawaii, with their tendency to puddle, humus is especially needed. The organic material supplied by plowing under leguminous crops lightens the soil, improves the drainage, and by its decay makes the phosphoric acid and potash in the soil more available to following crops. The chief value of legumes is, however, in the nitrogen which they add to the soil. As is well known,

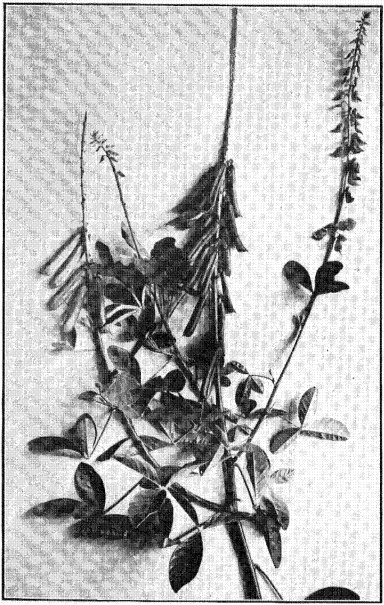

Fig. 1. *Crotalaria saltiana*, one of the wild "rattlepods" recommended as a green manure. The canoe-shaped pods are light yellowish brown in color and contain yellow seeds.

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they differ from most other plants in that the bacteria, which live on their roots and form nodules resembling small warts, are able to take up nitrogen from the air and change it into a form which the plants can use. When the legumes are plowed under, the nitrogen they contain is added to the soil, increasing the supply upon which the succeeding crops can draw.

NITROGEN CONTENT OF LEGUME VARIETIES.

In experiments conducted by the chemical department of this station, 32 varieties of legumes were grown on two soils of different types. One soil was a dark brown clay from the station grounds, the other, an acid red clay from the Kunia district of the Island of Oahu. Three crops were grown of each of the 32 varieties of legumes, using 4 pots for each trial of each variety. At maturity, the plants were removed, weighed, and analyzed for nitrogen. Analyses of the soil for nitrogen were made before planting and after removing the crop. These analyses indicate that a large portion, at least, of the nitrogen in the legumes was obtained from the air through the associated root-tubercle bacteria.

The results of these experiments will be given in detail in a forthcoming publication by Alice R. Thompson, Assistant Chemist of this station, but as the projected bulletin is technical in character, it is thought that some of the data, presented in a less technical form, will be of popular interest and value. The yield of freshly cut stems and leaves (or green forage) appeared to be the most practical basis on which to estimate the nitrogen content of the different leguminous crops. The yields on this basis can be ascertained with little trouble by mowing and weighing the crop from a small measured area.

The approximate nitrogen content of the various legume varieties, calculated on the above basis, is given in Table I. Six varieties of cowpeas were grown, including the Whippoorwill, Taylor, Redripper, Brabham, Black, and mixed, but the results for these different varieties agreed so closely that they were averaged. The results for the four velvet beans grown, including the Mauritius, Florida, Lyon, and Brazilian, also agreed very closely and were averaged.

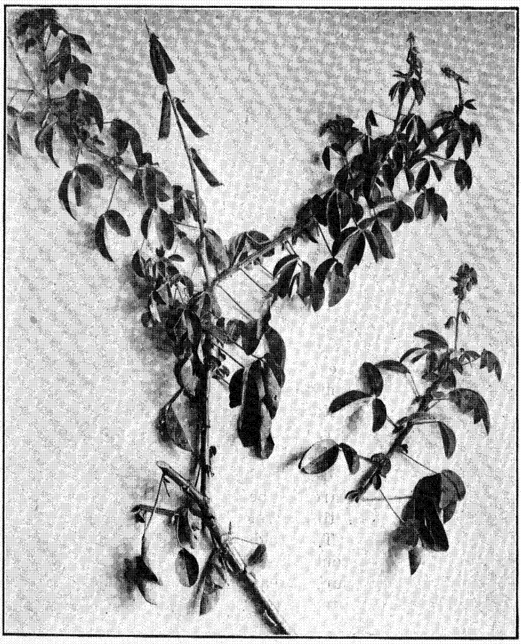

Fig. 2. *Crotalaria incana*, one of the wild "rattlepods" recommended as a green manure. This rattlepod is distinguished from the similar one shown in Fig. 1 by the fine hairs on the stems, leaves, and pods. The pods are black in color with dark or greenish seeds.

TABLE I. *APPROXIMATE NITROGEN CONTENT OF LEGUME VARIETIES.*

(Calculated on the basis of a ton of fresh cut stems and leaves).

VARIETY	Nitrogen in total plant lbs.	Nitrogen in stems and leaves lbs.	Nitrogen in roots lbs.
Sunn hemp (*Crotalaria juncea*)	20.2	16.0	4.2
Indigo plant (*Indigofera anil*)	28.4	20.4	8.0
Rattlepod (*Crotalaria saltiana*)	23.5	15.3	8.2
Rattlepod (*Crotalaria incana*)	18.9	15.9	3.0
Oregon vetch	20.0	12.3	7.7
Jack bean (*Canavali ensiformis*)	16.3	15.0	1.3
Velvet beans	14.0	11.7	2.3
Otootan soy bean	20.0	15.7	4.3
Partridge pea (*Cassia chamaecrista*)	23.7	19.6	4.1
Cowpeas	12.1	10.6	1.5
Hairy vetch	13.3	9.4	3.9
Florida beggar weed (*Desmodium tortuosum*)	19.0	15.6	3.4
Barchet soy bean	21.2	15.6	5.6
Spanish clover (*Desmodium uncinatum*)	19.8	12.8	7.0
Sesbania aegyptiaca	11.4	7.1	4.3
German lupine	8.7	7.1	1.6
Phaseolus semierectus	17.3	13.6	3.7
Mung bean (*Phaseolus mungo*)	15.5	13.8	1.7
Kulthi (*Dolichos biflorus*)	12.5	11.6	0.9
Sensitive plant (*Mimosa pudica*)	13.7	6.8	6.9

Table I gives the name of the variety of legume and the amount of nitrogen in the stems and leaves, in the roots, and in the total plant, calculated on a basis of a ton of fresh cut stems and leaves. That is, if a crop of legumes is cut and weighed while fresh, then in each ton of the weighed stems and leaves and in the roots belonging to that ton, there will be approximately the amount of nitrogen

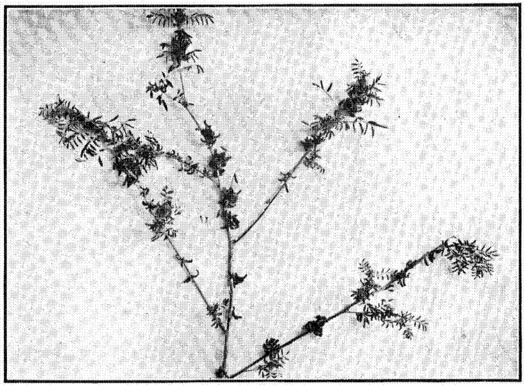

Fig. 3. Indigo plant (*Indigofera anil*), a leguminous weed very high in nitrogen. Easily identified by the clusters of tiny black pods resembling miniature bunches of bananas.

shown in the table. If a grower, for example, wishes to know how much nitrogen a crop of sunn hemp will add to his soil when turned under, he can go to his field and cut a known area, as one-tenth of an acre, and weigh the stems and leaves cut. If they weigh say, 1.8 tons, then in the stems and leaves cut there will be 16 pounds of nitrogen per ton, and in the roots left in the ground, 4.2 pounds, making a total of 20.2 pounds of nitrogen per ton, or 36.4

pounds for the 1.8 tons. For the whole acre, there would be ten times this amount or 364 pounds of nitrogen.

It is to be understood of coure, that the figures in Table I are only approximate. They are the average of a large number of pot experiments which do not exactly duplicate field conditions.

The amount of nitrogen in a given legume is not absolutely constant but varies to some extent with different conditions of soil and climate. However, the figures given are sufficiently representative for ordinary calculations, and as they are based on crops grown under similar conditions, they should be of considerable value in comparing the different legume varieties. Although the crops grown on poor soil were smaller than those on good soil, the amounts of nitrogen calculated on the basis of a ton of fresh cut stems and leaves were found to agree fairly closely for both soils.

YIELDS AND TIME REQUIRED FOR MATURING DIFFERENT LEGUMES.

In order to compare the amounts of nitrogen added to the soil by different legumes, the yields of the different legumes and also the time necessary to mature a crop for green-manuring must be considered.

Data on yields and growing time are given in Table II, in which comparisons are also made of the nitrogen-adding value of the different legumes.

TABLE 2. *COMPARATIVE NITROGEN ADDING VALUES OF VARIOUS LEGUMES GROWN AS GREEN MANURES.*

VARIETY	Estimated tonnage of fresh cut stems and leaves per acre		Approximate nitrogen content of total plant per ton of fresh cut stems and leaves.	Estimated nitrogen added to soil per acre by an average crop turned under.	Estimated time necessary to mature crop for green manure.
	Range	Average			
	TONS	TONS	POUNDS	POUNDS	MONTHS
Sunn hemp (*Crotalaria juncea*)	10 to 26	18	20.2	364	3
Indigo plant (*Indigofera anil*)	8 to 16	12	28.4	341	6
Rattlepod (*Crotalaria saltiana*)	8 to 20	14	23.5	329	3
Rattlepod (*Crotalaria incana*)	10 to 24	17	18.9	321	3
Oregon vetch	9 to 19	14	20.0	280	5
Jack bean (*Canavali ensiformis*)	12 to 20	16	16.3	261	5
Velvet beans	12 to 24	18	14.0	252	4.5
Otootan soy bean	6 to 16	11	20.0	220	4
Partridge pea (*Cassia chamaecrista*)	5 to 12	8.5	23.7	201	3.5
Cowpeas	10 to 20	15	12.1	182	3
Hairy vetch	8 to 18	13	13.3	173	6
Florida beggar weed (*Desmodium tortuosum*)	6 to 12	9	19.0	171	6
Barchet soy bean	6 to 10	8	21.2	170	4
Spanish clover (*Desmodium uncinatum*)	5 to 10	7.5	19.8	149	3.5
Sesbania aegyptiaca	10 to 14	12	11.4	137	4
German lupine	12 to 18	15	8.7	131	3.5
Phaseolus semierectus	5 to 8	6.5	17.3	112	3
Mung bean (*Phaseolus mungo*)	4 to 10	7	15.5	109	3
Kulthi (*Dolichos biflorus*)	6 to 10	8	12.5	100	4.5
Sensitive plant (*Mimosa pudica*)	2 to 4	3	13.7	41	6

Table II gives the kind of legume, the range in yield and average tonnage of fresh cut stems and leaves per acre, data obtained from numerous field trials by the agronomy department; and the amount of nitrogen in the total plant per ton of fresh cut stems and leaves, as given in Table I. In addition Table II shows the estimated amount of nitrogen added per acre by turning under the average crop of each legume. These figures are obtained by multiplying the average tonnage of fresh cut stems and leaves per acre by the pounds of nitrogen in the total plant. While crop yields are affected by the rainfall, the season, the soil, etc., still these figures, based on an average crop production,

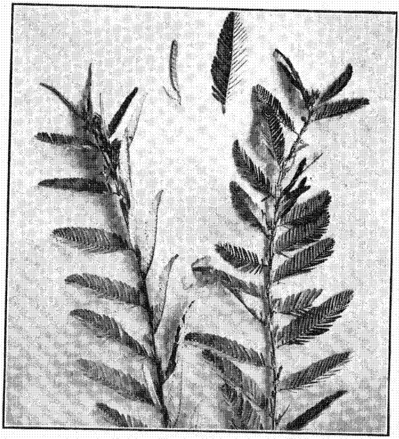

Fig. 4. Partridge Pea or Japanese tea. (*Cassia chamaecrista*), a leguminous weed high in nitrogen. Easily recognized by its yellow flower and its similarity to the sensitive plant.

should be of considerable value in comparing the nitrogen adding efficiency of the different legumes and in indicating desirable varieties.

The estimated time required to mature a crop for a green manure also appears in Table II. These figures should be taken into consideration where time is an important factor or several leguminous crops are to be grown in succession.

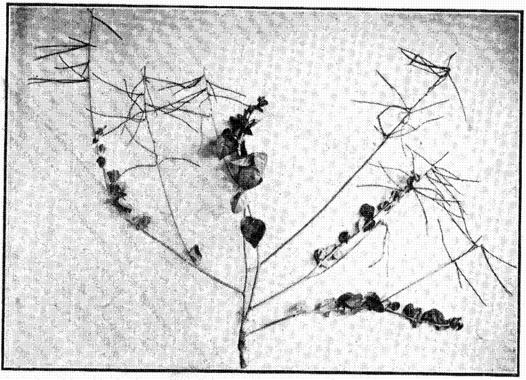

Fig. 5. *Phaseolus semi-erectus.* When thickly sown on worn out pasture land, this legume has been found of considerable value as a green manure.

DESCRIPTION OF VARIETIES.

Nearly all the cultivated legumes mentioned in the above tables are well known. These legumes have been described in a previous publication of the station.[1]

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[1] Hawaii Sta. Bul. 23 (1911).

Seven of the legumes given in the tables occur commonly as weeds in Hawaii. Of these the most important appear to be the wild "rattlepods" (*Crotalaria saltiana* and *Crotalaria incana.*) These rattlepods grow wild and seem adapted to nearly every kind of soil and climate occurring in Hawaii. An abundant supply of seed can be easily obtained by gathering the pods from the wild plants and allowing them to dry on a large cloth in the sun. The seeds which are expelled from the pods on drying are easily separated for planting.

Some of the advantages of the *Crotalaria saltiana* have been mentioned in a previous publication of this station.[1] Because of the high nitrogen content of the wild rattlepods as shown in the tables, and their adaptability to soil and climatic conditions suitable for the cultivation of pineapples, they are recommended as a green manure for the preparation of pineapple fields. These rattlepods are also especially valuable as a green manure for the manganese soils of Oahu, as they are about the only legumes apparently uninjured by the black manganiferous soils.

The chief objection to these wild rattlepods is the woody character of their stems which causes some difficulty in turning them under. This woody character appears to the writers, however, as of considerable advantage in other ways under Hawaiian conditions. Under mainland conditions, with the short period from planting to harvest of the main crop, a lush, rapidly decaying and humifying green manure such as the cowpea is desirable. Under the semitropical Hawaiian conditions, rapid decay is undesirable as the humus is soon "burnt out" of the soil. With a crop such as pineapples, requiring a long growing period, the slower decay resulting from the more woody character of the stems, would appear to constitute a recommendation for these wild rattlepods as green manures.

Other legumes given in the tables which occur commonly as weeds are the indigo plant, (*Indigofera anil,*) partridge

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[1] Hawaii Sta. Rpt. (1914), p. 21.

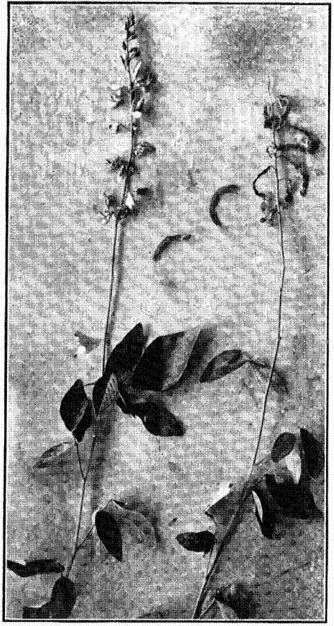

Fig. 6. Spanish Clover (*Desmodium uncinatum*). A thorough disking is sufficient preparation for planting this legume.

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pea (*Cassia chamaecrista*), *Phaseolus semierectus,* and Spanish clover (*Desmodium uncinatum*), illustrated in figures 3, 4, 5, and 6, respectively. Because of its well known appearance and non-importance as a green manure, the sensitive plant is not given. Under certain conditions it may be advisable to grow some of these other leguminous weeds as a green manure, especially the *Indigofera* and the *Cassia* which have a very high nitrogen content. The principal object in including these weeds in the tables, however, is to show the store of nitrogen they contain, and to indicate that, in preparing new land, these leguminous weeds should be plowed under to add their nitrogen to the soil instead of being burned off, as is the usual practice.

VALUE OF NITROGEN ADDED TO SOIL BY GREEN MANURE.

From the estimated amount of nitrogen added per acre by turning under the average crop of each legume, it is very easy to estimate the value of the nitrogen added to the soil. Twenty cents per pound is a low figure for organic nitrogen in commercial fertilizers, and the value of the nitrogen added by an average crop of sunn hemp (364 pounds) or of cowpeas (182 pounds) is apparent. Experiments at the Illinois Agricultural Experiment Station [1] with typical legumes show that about 45 per cent of the nitrogen in the tops of legumes is in water-soluble form and as such could be easily changed into a form available for following crops. Experiments conducted at this station show that the ammonification and nitrification (the changes which render the nitrogen available for following crops) of the nitrogen in cowpeas, turned under in the soil, compare very favorably with the ammonification and nitrification of dried blood under similar conditions.

SUMMARY.

1. A table is given showing for a large number of legumes the approximate amount of nitrogen in the roots, in the stems, and leaves and in the total plant. From this table, each individual farmer can calculate, by determining the crop yield on a small portion of his field, the approxi-

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[1] A. L. Whiting, Illinois Sta. Bul. 179 (1915), p. 540.

mate amount of nitrogen that a leguminous crop will add to his soil when plowed under.

2. A second table shows the range in yields, and average crop yields for various legume varieties on soils of ordinary fertility, together with the approximate amount of nitrogen that an average crop of each legume variety will add to the soil if plowed under.

3. The sunn hemp and the wild "rattlepods" appear to be among the legumes possessing the highest nitrogen adding efficiencies and are therefore recommended as green manures in Hawaii.

ACKNOWLEDGEMENT.

Thanks are hereby extended to Mr. J. E. Higgins, Horticulturist, for assistance in preparing the illustrations for this bulletin.

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Hawaii Agricultural Experiment Station

HONOLULU

J. M. WESTGATE, Agronomist in Charge

PRESS BULLETIN No. 53.

Composition and Digestibility of Feeding Stuffs Grown in Hawaii

By

MAXWELL O. JOHNSON, *Chemist*

and

KIM AK CHING, *Assistant Chemist*

INTRODUCTION

The present shortage in feeding stuffs and the possibility that communication between the mainland and the Hawaiian Islands may be interrupted demand that every effort should be made to increase the supply of feeding stuffs grown in Hawaii. The Hawaii Agricultural Experiment Station has issued at various times a number of publications[1] dealing with the cultivation of local crops for use as feeding stuffs.

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[1] Krauss, F. G., Hawaii Sta. Bul. 23 (1911); McClelland, C. K., Hawaii Sta. Bul. 36 (1915), Press Buls. 40 and 42 (1913). See also Hawaii Sta. Reports.

ANALYSES OF HAWAIIAN FEEDING STUFFS

In seeking new sources of supply of feeding stuffs, in determining their relative values, and in calculating rations for live stock, the determination of the chemical composition of feeding stuffs is of very great importance. The chemistry department of the Hawaii Agricultural Experiment Station has from time to time published analyses of samples of local feeding stuffs. The majority of these analyses were made by E. C. Shorey[1] and a number by Miss A. R. Thompson[2]. A number of analyses have been performed by the present chemist of the station. In order that the data secured may be of the greatest service in the present emergency, all the analyses so far made have been collected in Table I, where they are arranged in a form convenient for comparison with standard tables of American feeding stuffs, such as those of Henry and Morrison[3].

It is believed that the analyses of most of the important feeding stuffs produced in Hawaii are given in Table I. If any have been omitted, samples will be analyzed if about one pound of material in the condition in which it is usually fed to live stock is forwarded to the station.

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[1] Hawaii Sta. Bul. 13 (1913).

[2] Hawaii Sta. Rpt. 1907, pp. 63-66; 1908, pp. 58, 59.

[3] Henry, W. A., and Morrison, F. B. Feeds and Feeding. Madison, Wis., 1915, 15 ed., rev., pp. 691.

N. Y. P. L.
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TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates: Fiber	Carbohydrates: Nitrogen-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE						
NON-SACCHARIN AND SACCHARIN SORGHUMS:						
Sorghum:						
Sample No. 1	78.12	1.77	1.28	5.75	12.72	.36
Sample No. 2	62.56	2.88	1.98	10.15	22.05	.38
Sample No. 3	79.10	2.16	.77	8.23	8.98	.76
Sample No. 4	74.43	1.75	2.15	10.17	11.11	.39
Sample No. 5	81.50	1.60	.78	6.60	9.33	.19
Average	75.14	2.03	1.39	8.18	12.84	.42
Sugar-cane tops:						
Sample No. 1	71.12	1.64	1.60	7.20	18.09	.35
Sample No. 2	75.98	1.52	1.78	7.75	12.51	.46
Sample No. 3	76.30	1.50	1.23	6.98	13.54	.45
Average	74.47	1.55	1.54	7.31	14.71	.42
Hog or broom corn millet:						
Sample No. 1	75.53	1.79	2.81	7.45	12.05	.37
Sample No. 2	80.82	1.80	2.07	6.79	8.44	.08
Average	78.18	1.79	2.44	7.12	10.25	.22

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates Fiber	Carbohydrates Nitrogen-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
Kafir Corn:						
Sample No. 1	79.69	.97	1.65	6.66	10.86	.17
Sample No. 2	87.13	1.36	1.63	7.05	2.60	.23
Average	83.41	1.17	1.64	6.85	6.73	.20
GRASSES:						
Guinea grass:						
Sample No. 1	63.93	4.29	1.88	8.29	21.42	.19
Sample No. 2	65.02	3.45	2.03	11.68	17.39	.43
Average	64.48	3.87	1.95	9.98	19.41	.31
Para grass:						
Sample No. 1	79.72	2.07	2.00	7.89	8.18	.14
Sample No. 2	71.42	3.81	1.91	10.00	12.56	.30
Sample No. 3	71.51	2.11	2.66	11.68	11.61	.43
Sample No. 4	75.75	3.23	2.55	6.85	11.32	.30
Average	74.60	2.81	2.28	9.10	10.92	.29

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
Australian water grass (*Paspalum dilatatum*):						
Sample No. 1	75.77	2.47	2.82	7.32	10.97	.65
Sample No. 2	71.47	2.58	3.09	11.06	11.17	.63
Sample No. 3	72.95	2.13	1.96	8.86	13.38	.72
Average	73.40	2.39	2.62	9.08	11.84	.67
Paspalum orbiculare	57.13	3.70	2.13	13.65	22.93	.46
Barnyard grass	84.97	1.54	1.85	5.80	5.51	.33
Bermuda grass	45.49	5.36	3.71	12.50	32.62	.32
Buffalo grass	63.09	2.46	1.44	9.90	22.73	.38
Pilipiliuli (*Chrysopogon aciculatus*)	41.03	3.23	3.09	16.26	36.04	.36
Kukaipua (*Syntherisma sanguinalis*)	58.96	4.12	4.50	11.90	19.99	.53
Pili grass (*Heteropogon contortus*)	45.32	6.33	2.65	17.80	27.14	.76
Yard grass	77.77	2.72	1.87	7.45	9.17	1.02
Chloris elegans	64.85	4.20	2.75	11.25	16.44	.51
Hilo grass (*Paspalum conjugatum*):						
Sample No. 1	70.48	1.73	1.52	9.44	16.43	.40
Sample No. 2	71.70	1.76	1.43	9.39	15.18	.54
Sample No. 3	73.20	1.49	1.38	9.05	14.02	.86
Sample No. 4	70.07	2.47	1.41	8.96	16.28	.86
Average	71.36	1.86	1.43	9.21	15.48	.66

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
Rhodes grass	64.79	3.26	2.81	12.54	16.08	.52
Side oats grama (partly dried)	39.47	7.25	6.43	18.12	27.68	1.05
English and Italian rye grass (partly dried)	27.44	7.02	6.49	20.94	36.68	1.43
LEGUMINOUS FORAGE CROPS:						
Alfalfa:						
Sample No. 1	84.75	2.18	5.23	4.19	3.30	.35
Sample No. 2	68.13	3.60	7.31	10.32	10.20	.44
Sample No. 3	70.46	2.84	5.59	7.89	12.74	.48
Sample No. 4	76.61	2.87	6.78	4.24	8.73	.77
Sample No. 5	73.83	3.39	5.25	5.56	11.21	.76
Sample No. 6	72.18	3.39	8.00	6.27	9.44	.72
Average	74.33	3.04	6.36	6.41	9.27	.59
Cowpea:						
Sample No. 1	86.16	1.50	2.63	4.19	5.40	.12
Sample No. 2	82.35	2.55	3.06	4.22	7.24	.58
Average	84.26	2.02	2.84	4.21	6.32	.35

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
Wild cowpea (*Vigna sandwichensis*)	73.11	1.38	3.47	8.61	13.25	.18
Desmodium triflorum	65.22	2.76	5.03	11.65	13.92	1.42
Pigeon pea (*Cajanus indicus*)	70.00	2.64	7.11	10.72	7.88	1.65
Jack bean (*Canavali ensiformis*)	76.81	2.70	5.21	6.36	8.44	.48
Spanish clover *Desmodium uncinatum*	75.06	.98	2.20	7.21	14.36	.19
WEEDS USED AS FORAGE:						
Pigweed (*Portulaca oleracea*)	95.20	.96	1.04	.53	2.18	.09
Pualele (*Sonchus oleraceus*)	87.13	1.93	1.78	2.57	5.85	.74
Honohono (*Commelina nudiflora*):						
Sample No. 1	86.45	1.47	1.17	2.64	7.78	.49
Sample No. 2	92.41	1.33	1.38	1.92	2.81	.15
Average	89.43	1.40	1.27	2.28	5.30	.32
Ki or Spanish needles (*Bidens pilosa*):						
Sample No. 1	67.92	2.74	2.15	7.15	19.59	.45
Sample No. 2	82.06	2.65	3.45	5.03	6.48	.33
Average	74.99	2.69	2.80	6.09	13.04	.39

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
MISCELLANEOUS GREEN FORAGE:						
Prickly pear:						
Young fronds	94.63	1.12	.44	.52	3.22	.07
Old fronds	94.62	1.13	.39	.61	3.16	.09
Average	94.63	1.12	.41	.57	3.19	.08
Kolu (*Acacia farnesiana*)	60.00	2.10	6.87	7.16	23.04	.83
Banana tops	84.29	1.74	2.08	4.91	6.62	.36
Banana butts	94.22	1.05	.37	2.20	2.02	.14
Taro tops	84.56	1.38	1.86	1.42	10.29	.49
Sweet potato tops	87.67	1.27	2.93	1.69	6.08	.36
Ti (*Cordyline terminalis*) leaves	79.36	1.87	2.86	6.38	8.90	.63
Pakana (*Melilotus officinalis*)	61.28	2.60	5.96	11.90	17.59	.67
Rape	86.10	2.71	2.24	1.76	6.60	.59
Annual ilima (*Sida sp.*)	77.58	3.53	3.93	5.69	8.88	.39
Sisal waste (average of all samples)	84.11	1.58	.94	2.79	10.58	.00

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
FRESH GREEN ROUGHAGE—con.						
ROOT CROPS USED AS FORAGE:						
Cassava peeling	68.75	2.86	.99	3.58	23.30	.52
Cassava peeled roots	65.30	.55	.69	.71	32.62	.13
Cassava whole roots:						
Sample No. 1	65.55	.72	.71	.92	31.94	.16
Sample No. 2	62.80	1.00	.83	1.45	30.89	3.03
Average	64.17	.86	.77	1.19	31.42	1.59
Cassava refuse (from crude extract of starch)	15.46	.85	1.21	5.45	76.93	.10
Cassava waste (first washing for starch manufacture)	16.30	1.27	1.31	1.08	79.82	.22
Edible canna:						
Sample No. 1 (2 inch rootstocks)	81.58	.81	1.37	.54	15.57	.13
Sample No. 2 (5-6 inch ")	65.86	.81	1.20	.64	31.34	.15
Average	73.72	.81	1.28	.59	23.46	.14

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Taro waste	70.73	4.36	.36	.89	23.42	.24
Tacca pinnatifida	66.89	.84	1.93	.58	29.64	.12
Beet, yellow tankard	94.12	1.25	1.00	.97	2.62	.04
Beet, long red	93.25	1.17	1.13	2.59	1.80	.06
Ti (*Cordyline terminalis*) root (fresh)	67.34	.49	2.06	2.12	27.92	.07
Ti root (partly dried)	46.78	1.62	3.76	5.40	42.32	.16
Taro whole root	60.55	.73	1.10	.58	36.91	.13
Taro peeling	78.75	1.01	.66	1.23	18.14	.21
Taro peeled root	58.35	.69	1.16	.51	39.17	.12
Sweet potato whole root	68.89	.90	2.12	.81	27.02	1.26
Sweet potato peeling	74.35	.31	1.29	.33	21.63	1.09
Sweet potato peeled root	68.50	.94	2.18	.77	27.41	.20
SILAGE:						
Sorghum silage	76.76	2.17	2.04	5.68	12.62	.73
Corn cut for silo	76.45	2.57	1.64	6.43	12.67	.24
Corn silage	81.63	5.04	2.06	4.35	6.61	.31
Para grass silage	80.48	1.69	1.15	8.47	7.94	.21

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates: Fiber	Carbohydrates: Nitrogen-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
DRIED ROUGHAGE						
Hay from Grasses:						
Redtop	8.84	5.95	3.38	35.48	45.14	1.21
Rhodes grass:						
Sample No. 1	10.87	13.19	9.00	27.36	38.05	1.53
Sample No. 2	11.75	7.15	6.08	30.20	42.51	2.31
Sample No. 3	9.87	7.64	7.25	29.21	44.64	1.39
Average	10.83	9.33	7.44	28.92	41.73	1.74
Panicum plicatum	9.14	15.87	4.62	23.36	45.32	1.69
Foxtail grass	9.97	10.58	8.40	31.76	38.20	1.09
Sudan grass	9.48	8.71	7.64	33.48	38.97	1.72
Tunis grass	9.48	9.06	5.68	36.45	37.94	1.39
Rescue grass	9.37	7.67	10.75	33.75	36.07	2.39
Australian blue grass	9.48	6.58	5.72	39.12	37.29	1.81
Natal redtop	9.46	8.37	4.25	38.01	38.10	1.81
Small Cereal Straws:						
Wheat straw	9.44	7.32	4.48	31.80	45.14	1.82
Wheat straw containing a little oats	11.91	10.83	7.96	30.09	38.27	.94
Rice straw	10.89	19.88	4.81	24.84	36.91	2.67

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates Fiber	Carbohydrates Nitrogen-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
DRIED ROUGHAGE—con.						
MEAL FROM HAY:						
Sudan grass meal	10.77	5.68	5.37	36.89	40.75	.54
Velvet bean vine meal (seed removed)	11.84	6.26	17.15	36.09	28.00	.66
Pigeon pea meal (seed removed)	10.15	3.70	16.53	42.86	25.54	1.22
Sunn hemp meal	10.71	3.19	10.67	45.89	29.00	.54
Cowpea vine meal (seed removed)	11.68	8.42	14.96	32.30	30.97	1.67
Mixed feed consisting of 2 parts velvet bean vine meal, 1 part Sudan grass meal, & 1 part cane-top meal	11.25	4.93	15.57	36.56	30.25	1.44
Mixed feed consisting of equal parts by weight of cowpea meal, algaroba meal, & molascuit (80% molasses)	11.61	7.67	13.65	23.81	42.25	1.01
ROOTS AND BY-PRODUCTS:						
Cassava peeling	12.00	8.07	2.80	10.09	65.57	1.47
Taro peeling	12.51	4.13	2.71	5.08	74.70	.87
Sweet potato peeling	12.81	1.06	4.37	4.51	73.56	3.69
Cassava whole root	12.43	1.83	1.81	2.34	81.18	.41
Taro whole root	12.13	1.63	2.46	1.29	82.20	.29
Sweet potato whole root	11.52	2.56	6.02	2.30	76.86	.74
Cassava peeled root	12.47	1.40	1.75	1.79	82.27	.32

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

Feeding Stuff	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
DRIED ROUGHAGE—con.						
Taro peeled root	12.09	.69	2.45	1.07	82.68	.25
Sweet potato peeled root	11.43	2.65	6.12	2.16	77.09	.55
Hog or broomcorn millet roots	11.18	12.83	7.22	40.82	27.56	.39
Miscellaneous:						
Sisal waste	5.00	11.24	5.78	17.97	60.01	.00
CONCENTRATES						
Brewers' Grains	9.05	3.71	18.06	20.34	46.08	2.76
Molascuit:						
Sample No. 1	26.00	7.02	4.20	7.00	55.68	.10
Sample No. 2	15.66	7.66	4.54	10.86	61.12	.16
Sample No. 3	21.95	9.20	2.27	6.96	59.57	.05
Average	21.20	7.96	3.67	8.27	58.80	.10

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates: Fiber	Carbohydrates: Nitrogen-free Extract	Fat
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
CONCENTRATES—con.						
Algaroba or Kiawe bean:						
Sample No. 1	15.61	2.89	9.37	22.88	48.62	.63
Sample No. 2	14.91	3.61	8.41	26.63	45.91	.53
Sample No. 3	13.62	3.33	8.13	21.87	52.38	.67
Sample No. 4	16.37	3.44	8.50	17.47	53.77	.44
Sample No. 5	15.17	3.82	9.73	23.71	47.12	.45
Average	15.14	3.42	8.83	22.51	49.56	.54
Algaroba meal:						
Sample No. 1	5.10	3.67	9.56	21.14	59.86	.67
Sample No. 2	9.29	3.52	10.25	27.85	47.98	1.11
Average	7.19	3.59	9.91	24.49	53.92	.89
Seed and pod 1 year old	11.36	3.17	9.87	23.65	51.52	.43
Seed and pod fresh bean	12.30	3.20	7.34	19.48	57.31	.37
Seed coats	12.57	2.06	5.00	32.74	47.26	.37
Selected pods, seed removed	18.15	2.68	6.52	20.20	53.33	.12
Seed from selected pods	14.38	4.44	33.62	6.84	36.78	3.94
Average pods, seed removed	17.49	3.15	4.62	22.52	52.07	.15
Seed from average pods	14.24	4.40	30.18	7.78	38.90	4.50

TABLE I.—PERCENTAGE COMPOSITION OF HAWAIIAN FEEDING STUFFS—Cont.

FEEDING STUFF	Water	Ash	Crude Protein	Carbohydrates		Fat
				Fiber	Nitrogen-free Extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
CONCENTRATES—con.						
Rice bran:						
Sample No. 1	9.55	12.16	7.12	28.97	31.19	11.01
Sample No. 2	10.63	10.07	11.33	10.33	45.57	12.07
Average	10.09	11.11	9.23	19.65	38.38	11.54
Rice polish	10.49	8.87	12.31	5.18	50.18	12.97
Coconut meal	11.18	5.74	20.97	12.97	41.62	7.52
Pigeon pea meal	9.67	4.51	19.08	10.57	54.49	1.68
Cowpea meal	9.86	3.72	20.88	6.33	57.47	1.74
Jack bean meal	7.18	3.81	21.53	9.91	55.06	2.51
Corn-and-cob meal	13.52	1.58	10.03	4.54	67.98	2.35
Velvet bean meal (seed and pod)	12.47	6.57	23.01	6.50	47.91	3.54
Soy bean waste (original)	77.68	2.96	4.90	.17	14.28	.01
Soy bean waste (air dry)	4.07	12.77	21.12	.74	61.26	.04
Sake waste	63.47	.58	14.84	1.67	18.76	.68
Molasses	23.33	8.66	2.34	.00	65.42	.25

The analyses in Table I were made according to the methods adopted by the Association of Official Agricultural Chemists.[1] The crude protein represents all the nitrogenous constituents of the feeding stuff and consists chiefly of the proteids, which are necessary to supply new tissue for replacing the body waste and for growth, milk production, etc. The fiber is the material left after boiling the sample with sulphuric acid and with caustic soda and represents roughly the woody matter. It has a low nutritive value, but a portion of it is digested by animals. The nitrogen-free extract represents the starch, sugar, and similar substances in the feed and usually has a high nutritive value. In Table I, the crude fiber and nitrogen-free extract are grouped together as carbohydrates, according to the method used by Henry and Morrison.[2] The fat represents the material extracted from the feeding stuff by ether. In concentrates such as middlings and oil meal, the so-called fat, or ether extract, consists mainly of fats and oils, but in roughages other substances may be present in large amount. The digested carbohydrates and fats are used to produce fat and to supply the energy necessary for work and for the body activities. Excess of digested protein may also be used for the same purposes. The ash represents the mineral constituents of the feeding stuff left after ignition. The importance of the mineral constituents to animals is being increasingly recognized. Lime and phosphoric acid are usually the most important. Shorey[3] has pointed out the very low lime content of many Hawaiian feeding stuffs and the value of his suggestions has been recognized by those raising live stock in Hawaii.

DIGESTIBILITY OF FEEDING STUFFS

It has been found by experiments on living animals in which the feed fed is weighed and analyzed as are likewise the excretory products, that only a part of the total amount of each nutrient in a feed is digested. Such experiments performed on a large number of animals are used in determining the average "coefficient of digestibility" for each nutrient, such as crude protein, fat, etc. This coefficient of digestibility represents the average percentage of the total amount of each nutrient which is digested by the animal body and thus becomes capable of utilization. It has been found by experiment that the digestibility of feeds is affected to some extent by a variety of causes, such as the kind of animal fed, the composition of the rations, the preparation of the feed, etc. The total amount of each nutrient in 100 pounds of a feed, multiplied by the coefficient of digestibility for that nutrient gives the average amount of the digestible nutrient per 100 pounds. Unfortunately, up to the present time, the necessary money and equipment have not been available for determining by an extensive series of slow and costly feeding experiments the average digestibility of Hawaiian feeding stuffs. Until such experiments can be carried out, it is necessary to assume that the average digestibility of the nutrients in the various Hawaiian feeding stuffs is approximately the same as for similar materials produced on the mainland for which digestibility data have been secured. Since a comparison of the analyses of the various Hawaiian feeding stuffs with similar mainland materials shows that their compositions are similar, there would probably not be very great error in assuming similar digestibilities. On this assumption it is possible to calculate approximate digestible nutrients of Hawaiian feeding stuffs, which, though not strictly accurate, are of value as the best data available at present. It should be remembered that all figures showing digestible nutrients in feeding stuffs are only approximate, as digestibility is a variable factor for which average values only can be secured. The approximate digestible nutrients of Hawaiian feeding stuffs are given in Table II.

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[1] U. S. Dept. Agr., Bur. of Chem. Bul. 107 (1907), pp. 38-58.

[2] Loc. cit.

[3] Loc. cit.

TABLE II

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

Feeding Stuff	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
FRESH GREEN ROUGHAGE						
Non-Saccharin and Saccharin Sorghums:						
Sorghum	24.86	.6	13.9	.3	15.2	24.3
Sugar-cane tops	25.53	.7	14.8	.3	16.2	22.1
Hog millet	21.82	1.5	12.1	.1	13.8	8.2
Kafir corn	16.59	1.0	8.6	.1	9.8	8.8
Grasses:						
Guinea grass	35.52	.9	18.4	.2	19.7	20.8
Para grass	25.40	1.1	10.0	.1	11.3	9.2
Australian water grass (*Paspalum dilatatum*)	26.60	1.2	10.5	.3	12.4	9.3
Paspalum orbiculare	42.87	1.0	18.3	.2	19.7	18.7
Barnyard grass	15.03	1.3	7.9	.2	9.6	6.4
Bermuda grass	54.51	1.8	22.5	.1	24.5	12.6
Buffalo grass (*manie-akiaki*)	36.91	.8	19.7	.2	20.9	25.1
Pilipiliuli (*Chrysopogon aciculatus*)	59.00	1.5	26.1	.2	28.0	17.6
Kukaipua (*Syntherisma sanguinalis*)	41.04	2.2	16.0	.2	18.6	7.4
Pili grass (*Heteropogon contortus*)	54.68	1.3	22.5	.4	24.7	18.0
Yard grass	22.23	1.3	11.8	.6	14.4	10.0
Chloris elegans	35.15	1.3	13.8	.2	15.5	10.9
Hilo grass (*Paspalum conjugatum*)	28.64	.7	12.3	.3	13.6	18.4

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

Feeding Stuff	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
FRESH GREEN ROUGHAGE—Con.						
Rhodes grass	35.21	1.3	17.6	.3	19.6	14.0
Side oats grama (partly dried)	60.53	3.1	22.9	.5	27.1	7.7
English and Italian rye grass (partly dried)	72.59	5.1	42.8	1.0	50.1	8.8
LEGUMINOUS FORAGE CROPS:						
Alfalfa	25.68	4.7	9.4	.2	14.5	2.0
Cowpea	15.74	2.2	7.6	.2	10.2	3.6
Wild cowpea (*Vigna sandwichensis*)	26.89	2.6	14.9	.1	17.7	5.8
Spanish clover *Desmodium uncinatum*	24.94	1.6	14.9	.1	16.7	9.4
Desmodium triflorum	34.78	3.8	17.1	.8	22.7	4.9
Pigeon pea (*Cajanus indicus*)	30.00	5.5	10.7	.9	18.2	2.3
Jack bean (*Canavali ensiformis*)	23.19	4.0	9.8	.3	14.5	2.6
WEEDS USED AS FORAGE:						
Pigweed (*Portulaca oleracea*)	4.80	.9	2.5	.0	3.4	2.8
Pualele (*Sonchus oleraceus*)	12.87	1.1	6.9	.3	8.6	6.8
Honohono (*Commelina nudiflora*)	10.57	.8	6.2	.1	7.2	8.0
Ki or Spanish needles (*Bidens pilosa*)	25.01	1.8	15.6	.1	17.6	8.7

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

Feeding Stuff	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
MISCELLANEOUS GREEN FORAGE:						
Prickly pear	5.4	.2	2.8	.1	3.2	15.0
Kolu (*Acacia farnesiana*)	40.00	5.3	20.5	.4	26.7	4.0
Banana tops	16.71	1.3	9.4	.1	10.9	7.4
Banana butts	5.78	.2	2.6	.1	3.0	14.0
Taro tops	15.46	1.2	9.7	.2	11.3	8.4
Sweet potato tops	12.33	1.9	6.4	.1	8.5	3.5
Ti (*Cordyline terminalis*) leaves	20.64	1.8	12.4	.2	14.7	7.1
Pakana (*Melilotus officinalis*)	38.72	4.5	17.7	.3	22.8	4.0
Rape	13.90	2.0	7.6	.3	10.2	4.1
Annual ilima (*Sida sp.*)	22.42	2.0	8.9	.2	11.3	4.6
Sisal waste	15.89	.5	8.1	.0	8.6	16.2
SILAGE:						
Para grass silage	19.52	.6	10.1	.1	10.9	17.1
Sorghum silage	23.30	.9	11.3	.4	13.1	13.5
Corn silage	18.40	1.1	7.3	.2	8.8	7.0
Corn cut for silage	23.55	1.0	13.9	.2	15.3	14.3
ROOT CROPS AS FORAGE:						
Cassava whole root	35.83	.5	30.5	1.4	34.1	67.2
Cassava peeling	31.25	.6	23.8	.5	25.5	41.5
Cassava peeled root	34.70	.4	31.2	.1	31.8	78.5

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

FEEDING STUFF	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
FRESH GREEN ROUGHAGE—Con.						
Cassava refuse (from crude extract of starch)	84.54	.7	73.5	.1	74.4	105.2
Cassava waste (first washing for starch manufacture)	83.70	.8	72.7	.2	73.9	91.3
Edible canna	26.25	.8	22.5	.1	23.5	28.3
Taro waste	29.27	.2	21.8	.2	22.4	111.0
Tacca pinnatifida	33.11	1.1	28.3	.1	29.6	25.9
Ti root (*Cordyline terminalis*)	32.66	1.5	27.8	.1	29.5	18.6
Beet, yellow tankard	5.88	.7	2.9	.0	3.6	4.1
Beet, long red	6.75	.8	2.6	.1	3.6	3.5
Taro whole root	39.45	.6	35.1	.1	35.9	58.8
Taro peeling	21.25	.4	17.3	.2	18.1	44.2
Taro peeled root	41.65	.7	37.2	.1	38.1	53.4
Sweet potato whole root	31.11	1.3	26.0	1.1	29.8	21.9
Sweet potato peeling	25.65	.8	19.7	1.0	22.7	27.3
Sweet potato peeled root	31.50	1.3	26.4	.2	28.1	20.6

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

FEEDING STUFF	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
DRIED ROUGHAGE						
HAY FROM GRASSES:						
Redtop	91.20	2.0	50.1	.6	53.4	25.7
Rhodes grass	89.17	3.8	43.8	.7	49.1	11.9
Panicum plicatum	90.86	2.6	43.1	.9	47.7	17.3
Foxtail grass	90.03	5.2	43.4	.6	49.9	8.5
Sudan grass	90.52	3.4	44.6	.8	49.8	13.6
Tunis grass	90.52	2.5	46.0	.6	49.8	18.9
Rescue grass	90.63	5.5	43.0	1.0	50.8	8.2
Australian blue grass	90.52	3.3	48.6	.9	53.9	15.3
Natal redtop	90.54	2.2	46.8	.7	50.5	21.9
SMALL CEREAL HAY:						
Wheat straw	90.60	1.0	32.6	.6	34.9	33.9
Rice straw	89.11	1.1	31.6	.6	34.0	29.9
MEAL FROM HAY:						
Sudan grass meal	89.23	2.4	47.9	.2	50.7	20.1
Velvet bean vine meal (seed removed)	88.16	11.7	34.0	.3	46.3	3.0
Pigeon pea meal (seed removed)	89.85	11.2	37.5	.5	49.8	3.5
Sunn hemp meal	89.29	7.3	41.9	.2	49.6	5.7
Cowpea vine meal (seed removed)	88.32	10.2	36.2	.7	47.9	3.7

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

FEEDING STUFF	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
DRIED ROUGHAGE—Con.						
Mixed feed consisting of 2 parts velvet bean vine meal, 1 part Sudan grass meal, 1 part cane-top meal	88.75	8.6	47.5	1.0	58.3	5.7
Mixed feed consisting of equal parts by weight of cowpea meal, algaroba meal, and molascuit (80 per cent molasses)	88.39	9.6	48.1	.7	59.2	5.1
ROOTS AND BY-PRODUCTS:						
Cassava peeling	88.01	1.7	66.9	1.3	71.5	41.0
Taro peeling	87.49	1.6	71.2	.8	74.6	45.6
Sweet potato peeling	87.19	2.6	69.7	3.3	79.7	29.6
Cassava whole root	87.57	1.0	77.1	.4	79.0	78.0
Taro whole root	87.87	1.5	78.3	.3	80.4	52.6
Sweet potato whole root	88.48	3.6	74.0	.7	79.1	21.0
Cassava peeled roots	87.53	1.0	78.7	.3	80.3	79.3
Taro peeled roots	87.91	1.4	78.5	.2	80.3	56.3
Sweet potato peeled roots	88.57	3.6	74.1	.5	78.8	20.8
Hog or broom corn millet roots	88.82	5.3	46.1	.3	52.0	8.8
MISCELLANEOUS:						
Sisal waste	95.00	3.0	47.8	.0	50.8	15.9

TABLE II—Con.

ESTIMATED DIGESTIBLE NUTRIENTS OF HAWAIIAN FEEDING STUFFS

Feeding Stuff	Total dry matter in 100 pounds	Digestible nutrients in 100 pounds				Nutritive Ratio
		Crude protein	Carbohydrate	Fat	Total	
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	1:
CONCENTRATES						
Brewers' grains	90.00	14.6	36.2	2.5	56.4	2.8
Molascuit	78.80	2.2	50.6	.1	53.0	23.0
Algaroba or kiawe bean	84.85	5.4	50.2	.4	56.4	9.4
Algaroba meal	92.81	6.0	54.8	.7	62.4	9.4
Algaroba meal, average pods, seed removed	82.51	2.8	52.4	.1	55.4	18.7
Algaroba meal, seed from average pods	85.76	24.7	41.1	3.3	73.2	1.9
Rice bran	90.01	6.0	35.2	8.9	61.2	9.2
Rice polish	89.50	8.2	47.0	10.5	78.8	8.6
Pigeon pea meal	90.33	15.6	57.4	1.2	70.4	3.5
Cowpea meal	90.20	17.1	57.5	1.3	77.5	3.5
Jack bean meal	92.82	17.7	57.5	1.9	79.4	3.4
Corn-and-cob meal	86.50	5.2	61.9	1.9	71.3	12.7
Velvet bean meal (seed and pod)	87.53	18.9	48.7	2.6	73.4	2.8
Soy bean waste (original)	22.40	4.5	14.4	.0	18.9	3.2
Soy bean waste (dried)	96.00	19.4	62.0	.0	81.4	3.2
Sake waste	36.53	9.6	15.2	.5	25.9	1.7
Molasses	76.67	1.4	51.7	.2	53.4	37.1
Coconut meal	88.82	18.9	39.2	7.5	74.9	2.9

In Table II, the digestible nutrients are estimated by combining the analyses of Table I with the table of the average digestibility of American feeding stuffs compiled by Henry and Morrison.[1]

No digestibility coefficients were available for some feeds, and in such cases, the coefficients of similar feeds were used. Because of the aproximate character of the whole table these cases were not given any special notation. The digestible protein in 100 pounds of a feeding stuff is found by multiplying the total crude protein in 100 pounds (as shown by the analyses in Table I) by the digestibility coefficient for crude protein in that feed. The digestible fiber and nitrogen-free extract are added together as digestible carbohydrate. The total of the digestible nutrients given in the sixth column of Table II was obtained by adding together the digestible protein, the digestible carbohydrates, and 2.25 times the digestible fat. The digestible fat is multiplied by 2.25 because of the fact that fat will produce 2.25 times as much heat as carbohydrates when used for suplying energy to the animal body.

THE NUTRITIVE RATIO

Because of the importance of protein to the animal body, the "nutritive ratio" is of value in calculating rations for live stock. This is the ratio of digestible crude protein to the other digestible nutrients in feeding stuffs. Since it is usually a fraction, it is expressed with a colon, as 1:8.9. It is found by dividing the sum of the digestible carbohydrates and 2.25 times the digestible fat by the digestible crude protein. The quotient is the second factor of the nutritive ratio. The nutritive ratio of a feed is said to be "narrow" when the proportion of crude protein to other nutrients is large, and to be "wide" when there is a small proportion of crude protein. For mixing feeds for dairy cattle a nutritive ratio of about 1:6 is usually recommended, while a wider ratio can be used for beef cattle. The nutritive ratios for the various Hawaiian feeding stuffs are given in the seventh column of Table II.

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[1] Loc. cit.

CALCULATION OF BALANCED RATIONS

Table II should be of use in estimating the relative values of the different Hawaiian feeding stuffs and determining the most promising local sources of supply. Table II can also be used in conjunction with tables of feeding standards for farm animals such as are given by Henry and Morrison[1] or by Fraps[2] for the calculation of rations for live stock. As the calculation of rations is rather a difficult process, the Hawaii Experiment Station will be glad to assist any who desire to make up a ration for a specific purpose if full data as to the feeds available and the animals to be fed (age, weight, for what purpose used, etc.) are sent to F. G. Krauss, Superintendent of the Extension Work, Haiku, Maui, or to the Hawaii Agricultural Experiment Station at Honolulu.

SUMMARY

(1) All the analyses of Hawaiian feeding stuffs made by the Chemistry Department of the Hawaii Experiment Station up to the present have been collected and arranged in a table convenient for comparison with standard tables of American feeding stuffs.

(2) On the assumption that the digestibility of Hawaiian feeding stuffs is about the same as for similar American feeding stuffs, a second table showing the approximate digestible nutrients of Hawaiian feeding stuffs has been prepared.

(3) These tables should be of use in estimating the relative values of different Hawaiian feeding stuffs, in determining the most promising local sources of supply to be developed, and in calculating rations for live stock.

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[1] Loc. cit.

[2] Fraps, G. S. Principles of Agricultural Chemistry. Easton Pa., 1913, pp. 493.

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Hawaii Agricultural Experiment Station
HONOLULU

J. M. WESTGATE, Agronomist in Charge.

PRESS BULLETIN No. 54.

Preliminary Report on Root Rot In Hawaii

(LAHAINA CANE DETERIORATION, PINEAPPLE WILT, TARO ROT, RICE ROOT ROT, BANANA ROOT ROT.)

By C. W. CARPENTER, *Pathologist.*

The term root rot is a collective term commonly applied loosely to root diseases of plants in general, but it is used in this preliminary report in a restricted sense to denote the most significant symptom found in such diseases as Lahaina cane deterioration so-called, pineapple wilt, etc. Such root rots or root failures are among the most important diseases of economic plants in Hawaii.

In this Territory, as in practically all sugar cane growing countries, a disease of the Lahaina cane (apparently the same as the Bourbon variety) of obscure origin has caused grave concern for many years. Many theories as to the cause of the so-called deterioration of this popular variety have been vigorously investigated without striking result in demonstrating the cause of the disease or in restoring this variety to culture in localities in which it has failed. In Hawaii the situation has been met in a very creditable manner by the Experiment Station of the Hawaiian Sugar Planters' Association through the development, selection, and propagation of resistant varieties, while in other countries other varieties have to a greater or less extent replaced the Bourbon type. Nevertheless, various theories as to the cause of failure have continued to be presented and investigated, an indirect tribute to the merit of the Lahaina variety. Of the latter there is no question, nor of the benefit to these Islands, could this variety be generally restored to profitable culture. Evidently the interest in the possible cause of failure of the Lahaina cane will not subside until a satisfactory explanation is found. The occurrence of the disease in plant cane on virgin soil, with the attack of another variety, H 146, and other manifestations of the increased virulence of the disease during the past year, have added to the seriousness of the situation.

Pineapples, second agriculturally only to cane in importance in these Islands, are attacked to an increasing extent by a root rot trouble popularly called "wilt." A similar disease is prevalent in other pineapple-growing countries. In the Hawaiian Islands, this disease has recently caused heavy losses with first plantings on virgin soil. With but the one preferred variety (Smooth Cayenne) of satisfactory quality, the situation as regards the future of this crop is admittedly grave. Evidently the past year has offered conditions unusually favorable to the development and spread of the pineapple "wilt" and the Lahaina cane disease.

In Hawaii the importance of root rots of other crops is perhaps less appreciated only because the crops affected are less extensively cultivated. The following diseases, in which root failure is a striking symptom or sign of disease, are considered as essentially in the same category as the Lahaina disease and pineapple "wilt" under discussion and are being studied simultaneously therewith, although the writer's investigation of these troubles was begun much earlier: Taro rot, banana root rot, (leaf chlorosis and center leaf necrosis), and a rarely observed, and little sought, it must be admitted, root rot of rice.

Preliminary investigations of root rot diseases of banana and taro were begun in October, 1916, and continued intermittently thereafter at favorable opportunities, with emphasis placed on this line of investigation the latter part of 1918. In January, 1919, typically diseased Lahaina cane and pineapple plants suffering from "wilt" were brought to the writer's attention. The first observations with the microscope were of such a convincing nature that the two diseases were immediately diagnosed as parasitic in character, of fungus origin, and apparently identical. The essential identity of the two diseases and their cause was announced in the local press on February 5, 1919.[1]

Considerable material included in the writer's unpublished reports is considered nonpertinent in the light of subsequent observations, but several sentences which are significant may well be quoted for the sake of record. Speaking of cane and pineapple root rot (February 4, 1919):

> "The undersigned wishes to go definitely on record as having observed in connection with and apparently causing the disease of the roots, a fungus. Apparently the mode of attack is somewhat as follows, basing the judgment on observations in the field, the statement of the planters, and the reaction of plants placed in water and left a few days, changing the water daily: The roots grow well until the

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[1] Pacific Commercial Advertiser, Honolulu, T. H.

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> fungus is encountered, and if the conditions of the soil are suitable, the root is attacked at the tip, in the vicinity of the root hairs, or a canker may form in advance of the point where the root hairs are found, etc. * * We may say, then, that the action of the fungus appears to be a *damping-off* of the roots somewhat in the same way as some *Rhizoctonias* damp-off the stems of seedlings. Sufficient data are not at hand to justify further views as to the method or mode of attack, the writer wishing chiefly to establish the priority of the view that a fungus is responsible for the diseased condition obtaining.
>
> "A fungus mycelium and hypha are found growing within the root hair cells of living young roots. Cankers apparently brought about by the same type of fungus are present on young roots, and when at the point of origin of the young roots or rootlets, girdle the same in some cases. This condition of root hair inhabitation and girdling exists in roots of both Lahaina cane and H 146 variety when suffering from root disease at Waipahu and in pineapple ("wilt") roots from Waipio and the foot of the Nuuanu Pali."

In this preliminary report it is not intended to furnish detailed information on the various root rot troubles under survey, but merely to outline the problem and supply a brief sketch of the working theory and results, and to record the essential identity of the diseases mentioned, together with the proof as to the cause of Lahaina disease so far as completed.

It is appreciated that more exhaustive studies may show several organisms capable of inducing root rot of our chief crops. If such is the case, the lack of characterization of the separate diseases necessarily makes difficult the determination of the individual causes. The writer's preliminary observations, in contrast to those of other investigators, having been such as to lead him to conceive of Lahaina deterioration and pineapple "wilt" as parasitic diseases of fungus origin, the parasite being active under certain soil conditions, and the two diseases being apparently identical in nature with several other root rots, the investigation of all was carried along at the same time in a systematic manner. Numerous organisms were isolated from the diseased roots in an attempt to obtain in pure culture a parasitic fungus corresponding to the one constantly seen in the sound tissues of the roots adjacent to those tissues showing the early stage of root disease (Pls. 4 and 5). After numerous disappointments, such a fungus was readily obtained, once the necessary technique was developed. This fungus from root rot of cane was found to closely resemble a fungus in cultivation for some years from taro rot and rice root rot. The similar mycelium and spores being present in the several root rots, rice, taro, cane, pineapple, and banana, and a parasitic type of fungus allied to *Pythium* having been isolated from the first three, it was believed that one definite cause of some of our root rot trouble had been found. The nature of this parasitic fungus now under investigation is such as to suggest lines of experimental work in laboratory and field, for determining possible control methods. Likewise, if this fungus is accepted as the cause of Lahaina disease and pineapple "wilt," the contradictory features of the two diseases are understandable (e. g. Pl. 2B).

It may be noted that a fungus theory as to the causes of the deterioration of Lahaina cane and pineapple "wilt" disease has been advanced many times by various investigators in several countries. As far as the literature examined indicates, no one seems to have linked the two diseases together, and in general results seem to have been negative or inconclusive, no proof being offered, so far as the writer is aware, that these diseases are caused by a fungus or other parasite. One of the fungi said[1] to be the cause of pineapple "wilt" is reported as a root hair inhabiting fungus. No proof of causal relation to the disease is offered.

It should be mentioned here that soon after announcement was made in the local press that apparently the cause of Lahaina disease and pineapple "wilt" had been found by the present writer, and the identity of these two diseases stated, H. L. Lyon,[2] of the Hawaiian Sugar Planters' Experiment Station reported the finding of resting spores of a protozoa-like organism, which he said probably belonged to the *Chytridineae,* in the affected roots of Lahaina cane and pineapples. He suggested the possible relation of these bodies to the disease and the possible identity of the diseases as to cause. He has subesquently noted[3] that if root diseased cane and pineapple plants are placed in water culture, without removing the rotted roots, new roots develop and after a time collapse, the same protozoan type spore bodies being present therein as in the original diseased roots. It was specifically stated that no mycelial fungus was associated with these bodies. These spore bodies mentioned by Lyon are considered by the present writer to be identical with those discussed in the following pages and are believed to be a definite stage in the development of the *Pythium*-like fungus. While some of the rounded spore bodies appear to be conidia (sporangia) and resting conidia, the majority are thought to be oospores within the remnants of the oogonium. The thick-walled spores generally are not found in the young lesions but abundantly in the softened tissues, and the mycelium which has preceded the oospores is generally not visible, though if searched for traces of it are occasionally seen attached to the vestiges of the oogonium-like wall surrounding the oospore (Pl. 7B).

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[1] Stockdale, F. A., Fungous disease of pineapples. West Indian Bulletin VIII, 1907, p. 159.

[2] Lyon, H. L., Root rot or "Lahaina disease." H. S. P. A. Expt. Sta., Progress of Work, January, 1919, p. 4. (Dated February 9, 1919.)

[3] Lyon, H. L., A preliminary report on the root rot organism. Hawaiian Planters' Record, vol. XXI, No. 1, July, 1919, pp. 2-8.

Studies conducted by the writer during the past seven months are a working out of the fungus theory conceived in January, 1919, and they serve not only to confirm the theory (Pls. 1, 2A, 3) but they offer strong proof that a fungus allied to *Pythium,* isolated from affected cane roots, is capable of causing a root failure in Lahaina cane. Without going into details, it may be said that one of the large number of fungi isolated from Lahaina cane, when grown in pure culture and placed in the steam-sterilized soil in which Lahaina cane was being grown in pots, produced root decay and strikingly checked the growth of the cane in a few weeks (Pls. 2A and 3). The seed in this test was top seed (cuttings) disinfected in 1:1,000 bichlorid of mercury for five minutes, planted in steam-sterilized soil, and watered only with distilled water. The latter item necessitated the conduction of the experiment on only a limited scale. The uninoculated control plants (Pl. 2A), as well as plants in soils inoculated with two other suspected fungi, developed vigorously the while and were soon about two feet higher than those in soil inoculated with the *Pythium*-like fungus, and the shoots were much larger and stronger in appearance. The root systems (Pl. 3) of the controls remained healthy, while those of the plants in inoculated soil were badly diseased. In the latter there was a striking lack of development of the hair-like feeding roots.

The fungus used for inoculation was recovered in pure culture from the diseased roots. This, in addition to the constant occurrence of an organism in association with a disease, is generally considered proof of causal relationship to the disease. Sufficient time has hardly elapsed to determine whether the fungus is constantly present in Lahaina disease, and it must be admitted that the number of plants inoculated in the test was small. The test must be repeated, and cross inoculations should be made with the same type fungus from the other host plants. Tests now under way show that the fungus forms some root lesions on H 109 and Yellow Caledonia varieties, both of which are resistant to the disease in the field. In other words, it appears that the resistance of these two varieties is relative, not absolute. *Pythium* sp. is not unknown as a root rot parasite of field crops, as it causes a serious root rot of sugar beets and other crops.

The observations of the writer in the field and the laboratory convince him that the same or a similar fungus is responsible for a most destructive type of pineapple "wilt" (root rot), and a root rot of taro, rice, and Chinese bananas (*Musa cavendishii*). The diseases are a damping-off of the roots and consequent checked development of the hair-like feeding roots, as conceived for Lahaina disease and pineapple "wilt", and are apparently caused by the so-called damping-off fungus of seedlings, *Pythium debaryanum,* or a related form. The mode of attack is as quoted above from the prognosis. The mycelium of the *Pythium*-like fungus is nonseptate when young, later becoming septate, and, in the roots of cane and banana at least, is often stained reddish-brown by the coloring matter liberated by the roots in response to the injury. The mycelium occurs in both the septate and the nonseptate form in the cells of the host tissue, and when in the epidermal cells of the roots, branches frequently run out into the root hairs. The most common points of attack are wherever tender young root tissue occurs, root tips, etc., or at any point on the young roots.

A positive identification of the fungus as to species is not necessary nor warranted at this time by the morphological studies, it being sufficient to state that in cultures as well as in the host tissue it resembles *Pythium debaryanum* (Pls. 5, 6, 7, 8.) The cane fungus with which a positive inoculation has been secured, with subsequent re-isolation of the fungus, is apparently identical with the taro root rot organism obtained in pure culture by the writer in May, 1918. In the roots after attack, as well as in culture, the fungus forms numerous conidia (sporangia) and resting spores (conidia and apparently oospores). These bodies are present at least in the affected tissues in the roots of cane, taro, pineapple, and banana, and in cultures from rice, taro, and cane. In pure cultures of the organism from rice, taro, and cane, undoubted oospores have been observed. Conidia and resting spores (oospores apparently) are also present in the affected and softened roots of Lahaina cane in soil inoculated with the pure culture of mycelium of the *Pythium*-like fungus. Swollen, globular mycelium, typically present in the diseased tissues, is thought to belong to this fungus (Pls. 4, 5, and 6).

Since the incubation period, i. e., in this case the time elapsing from inoculation of the soil to the advent of symptoms of disease (checked growth), was about two weeks, it is evident that the fungus requires only a short period of favoring conditions to initiate attack. In cane, possibly only in certain physical soil types, the time the soil is wet during periodic irrigations is probably sufficient for the infection of new roots which may have formed in response to the same and previous irrigations. In pineapples in the wilt-affected localities, there is probably sufficient precipitation to allow the attack to occur occasionally at least, or moisture conditions favorable to root development and extension are favorable to the fungus, and the attack may coincide with root extension. The symptoms, checked growth, etc., are subsequently manifested and become aggravated by periods of drought, when the plants lose more water by transpiration than the meager roots can supply. It is not extraordinary, if *Pythium* is the active agent in causing the disease, that such reported facts as simple removal of a wilt plant and replanting the same or another may give rise to a healthy growing plant.

In seeking to control a disease, logically the first step is to determine the cause, and then the conditions under which this cause is active. The writer's future studies for some time are designed to throw such additional light as may be possible on these preliminary phases of the problem, for without appreciation of these matters the finding of possible control methods is indeed remote. With further knowledge it will likely become evident whether or not practical control measures are within the range of probability. With taro rot it is of some significance that drying, resting, and aerating the sick soils, as well as the application of lime to the soil and the addition of copper sulphate to the irrigation water, respectively, have been markedly beneficial to the crop.

The fungus *Pythium,* which the root rot fungi under study closely resemble, is generally considered as favored by a stagnant condition of the soil, high soil temperature, and high moisture content. As already suggested in the writer's earlier unpublished reports, studies of the physical characteristics of our affected soils will likely prove of value in determining cultural modifications looking to control. In Java,[1] investigators reached the conclusion that a similar root rot there was not due to organisms found colonizing on the roots, among which *Pythium* is named, but to compacting the soil, etc. Since the Lahaina cane inoculation test above mentioned was conducted in good potting soil, and the control plants grew well, though treated in the same manner except that none of the *Pythium*-like fungus was introduced, the least that we can say is that our preliminary results support a conclusion at variance with the findings in Java. Whether the Java disease and the similar deterioration of the Lahaina type of cane in several other countries is the same as the disease occurring in the Hawaiian Islands is not known, though there is much in the literature indicating such identity.

In the Islands, especially as regards pineapple culture, field practice, groping in obscurity as to the cause of "wilt," has already made progress along the line that would be advised, should our further work confirm the preliminary conclusion that a species of *Pythium* or related fungus is the active cause of the wilt and root rot. Field practices most in favor for sometime have placed emphasis on drainage, aeration, etc., with hilling up as a means to this end. Flocculation of the soil particles of some soils at least is desirable, and in this connection it might be noted that common salt has been reported as of advantage in controlling damping-off diseases in greenhouses. In general, where the disease is present, an optimum supply of capillary water, with adequate soil aeration, is the indicated soil condition most likely to encourage healthy root development.

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[1] Kamerling, Z., Verslag van het Wortelrot, Oenderzoek, Soerabaia, 1903; abstracted by Sorauer, P., Manual of Plant Diseases, vol. I, pp. 227, 228.

SUMMARY.

1. Observations, field and laboratory studies confirm the theory advanced in February, 1919, as to at least one active cause of Lahaina disease (root rot) of cane. This cause is a parasitic fungus with a definite mycelium and of the *Pythium debaryanum* type. Apparently the same fungus or a closely related species is responsible for pineapple "wilt" (root rot), taro rot, banana center leaf necrosis (root rot), and a root rot of rice.

2. The parasitic fungus is the one observed and recorded in February, 1919, in cane and pineapple roots, attacked by Lahaina disease and "wilt," respectively, and is now, as then, found associated with lesions on the roots, near the tips, at the tips, and on other tender parts of the young roots indiscriminately, as well as existing as wandering hyphae, nonseptate to septate depending on conditions, in surface cells, root hair cells, and cells of the cortex of roots in the earliest stages of attack.

3. This type of fungus was first secured in pure culture from rice root rot in September, 1917, and from taro rot in May, 1918, and subsequent study in 1918 showed that the latter was capable of producing a rot of the taro corms. In taro rot in the field, the rot of the edible corm is preceded by a rot of the young roots as in cane and pineapples. The cane organism, isolated in pure culture and inoculated into steam-sterilized soil in which Lahaina cane from top seed disinfected in bichlorid of mercury solution 1:1,000 for five minutes was growing, attacked the roots. The plants were watered only with distilled water. Noticeable symptoms of disease appeared on the plants in about two weeks. The fungus was re-isolated in pure culture from this material.

4. This root rot fungus found parasitic on Lahaina cane is tentatively considered to belong to the *Pythiae* of the *Saprolegniaceae* and probably identical with *Pythium debaryanum.*

5. The nature of the fungus is such that, should further work substantiate the preliminary results, in our research we should tentatively put emphasis on physical studies of our soils in seeking control measures, and in the field studies give added attention to drainage and aeration, and possibly modify the physical properties through the application of chemicals which will flocculate our colloidal soils, if such chemicals can be found. With irrigated crops the addition of copper sulphate to the water may prove of value, as experiments have indicated with taro.

PLATES

PLATE 1. Comparative root systems of three-month-old Lahaina cane in sick Waipio soil (2); in same soil disinfected with formaldehyde (36); and in same soil steam-sterilized (12).

2. A, Lahaina cane, 60 days old, in steam-sterilized soil. Left, uninoculated control; right, in soil inoculated with the *Pythium*-like fungus five weeks before being photographed. (See Plate 3 for root systems.)

   B, A phenomenon of Lahaina cane disease in the field at Waipio; two sticks from the same stool, one of which succumbed and the other recovered. (Note the shortened internodes produced during period of diseased condition.)

3. Root systems of plants in Plate 2A. Control at left, plant in soil inoculated with *Pythium* at right.

4. Types of root hair and epidermal cell inhabitation by fungus mycelium in Lahaina cane root disease. A swollen, globular mycelium, as well as a cylindrical type, appears to belong to the *Pythium*-like fungus in a natural habitat. X 1000.

5. A, Portion of feeding mycelium in young root from base of sprout growing from seed piece (Lahaina cane). Apparent penetration of cell walls by amœboid processes. X 1000.

   B, Swollen, hyaline, finely granular feeding mycelium suggesting plasmodium. Root from joint of seed piece (Lahaina cane). X 1000.

   C, Tangential surface section of dark colored lesions on young root of Chinese banana (*Musa cavendishii*). Dark mycelium apparently stained brown by pigment from the discolored cell walls, etc. Note resemblance of mycelium to D from Lahaina cane. X 1000.

   D, Section of Lahaina cane root growing in steam-sterilized soil inoculated with the *Pythium*-like fungus. Some of the mycelium present has *Pythium*-like swollen ends and closely resembles that shown in C. X 1000.

6. Swollen globular mycelium apparently belonging to the *Pythium*-like fungus in a natural habitat. Note the wandering, attenuated portion penetrating the cell walls. This type of plasmodium-like mycelium is frequently found in Lahaina root disease, in the field material, as well as in affected roots in sterilized inoculated soil. This stage is thought to immediately precede resting spore formation. (Variety H 109 in inoculated soil.) X 1000.

7. A, Resting spore of *Pythium*-like fungus in cell of Lahaina cane root. Large numbers are typically present in the root disease after the tissues have partially broken down. They vary considerably in size and often are held to an oblong shape by the cell walls. Apparently these are oospores within vestiges of the oogonium wall. X 1000.

   B, Spores, similar to those in A, in cells of banana root. Barely visible traces of mycelium and possible antheridium still attached to the oogonium-like outer wall are indicated in the lower spore. X 1000.

8. A-D, *Pythium* from rice in culture (X 1000); A, Conidium (sporangium) or young oogonium forming; B, Egg cell (oosphere) developing in oogonium; C, Egg cell (a) being fertilized by antheridium (b); D, Thick-walled mature oospore (egg spore) freed from oogonium.

   E, *Pythium* in culture from Lahaina cane forming same sort of oospore (X 1000).; (a) egg cell or oosphere in oogonium, (b) oogonium, (c) antheridium(?).

   F, From the same culture as E. Fertilization effected, oospore with very thick brown wall.

   G, Root hair cell of Lahaina cane containing several spores. These are apparently hyaline oospores freed from the oogonia walls, or possibly resting sporangia (conidia). X 1000.

Note: Plates 4-8 from camera lucida drawings.

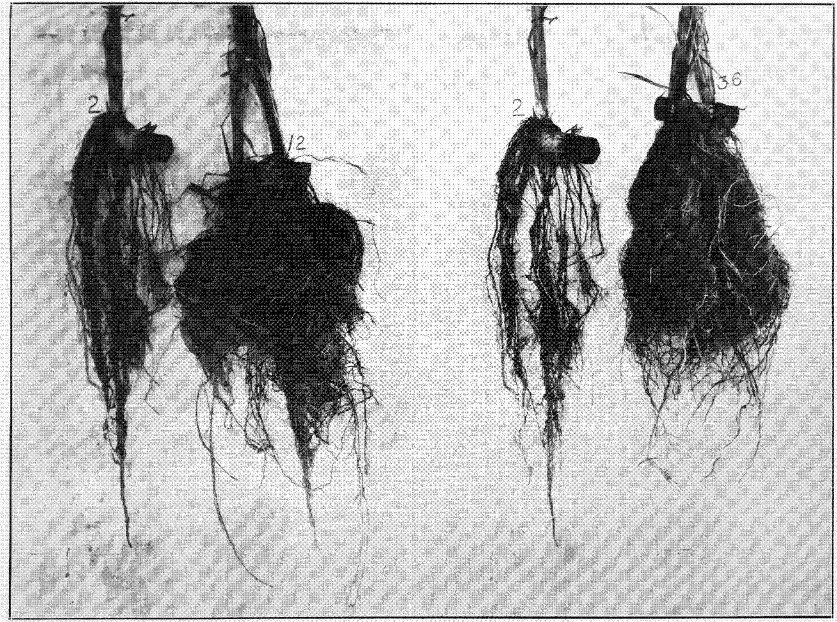
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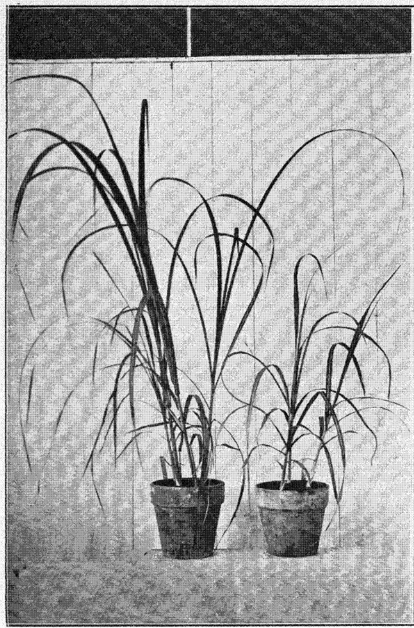
Plate 2.



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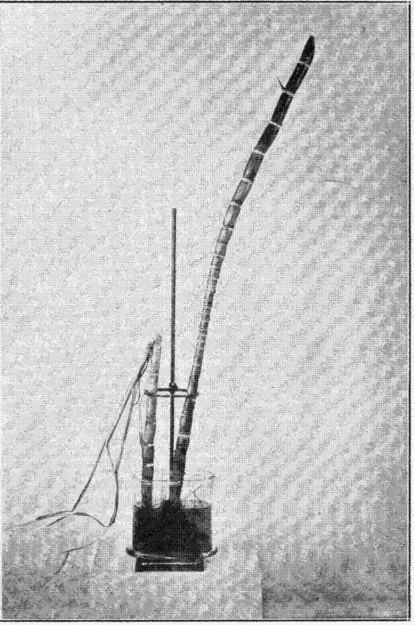
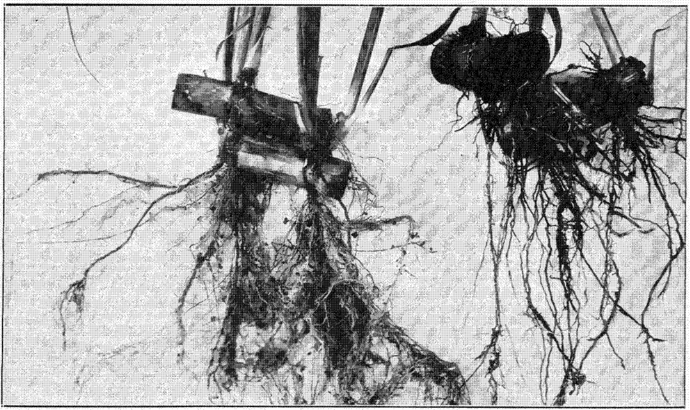
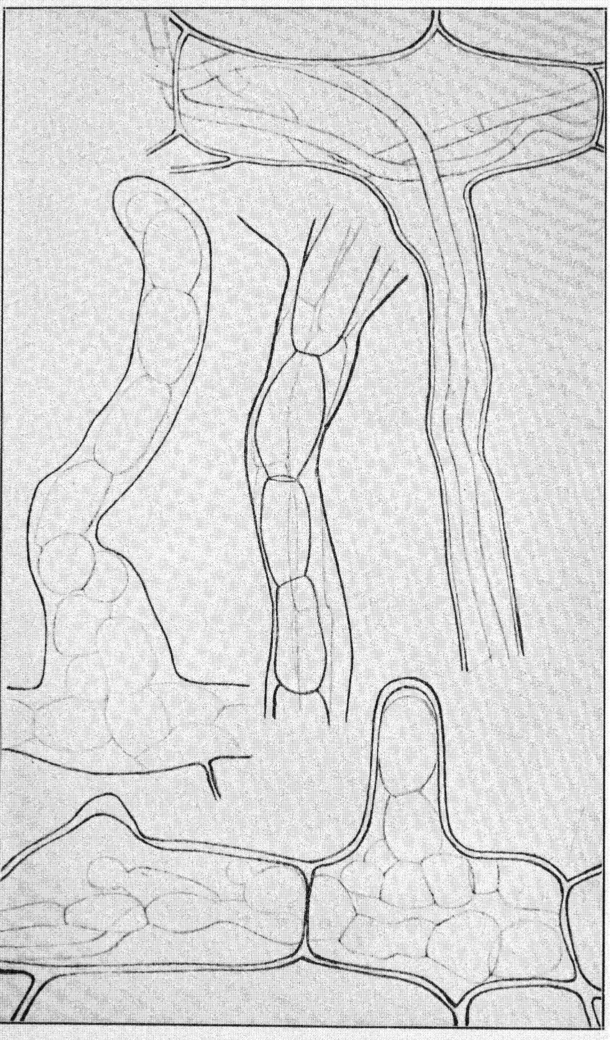
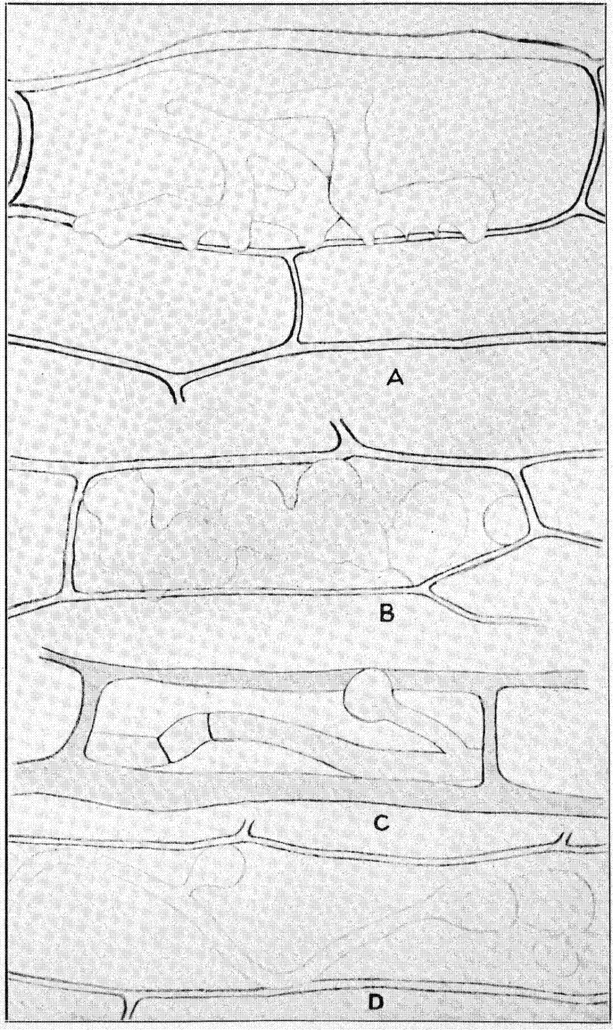


B

Preliminary Report on Root Rot in Hawaii. Plate 3.



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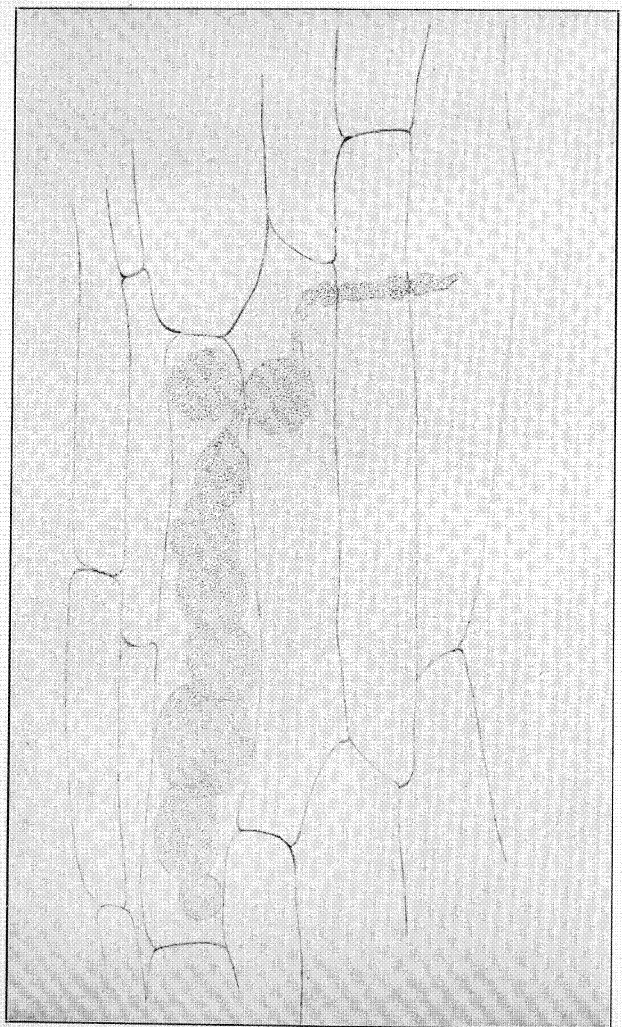

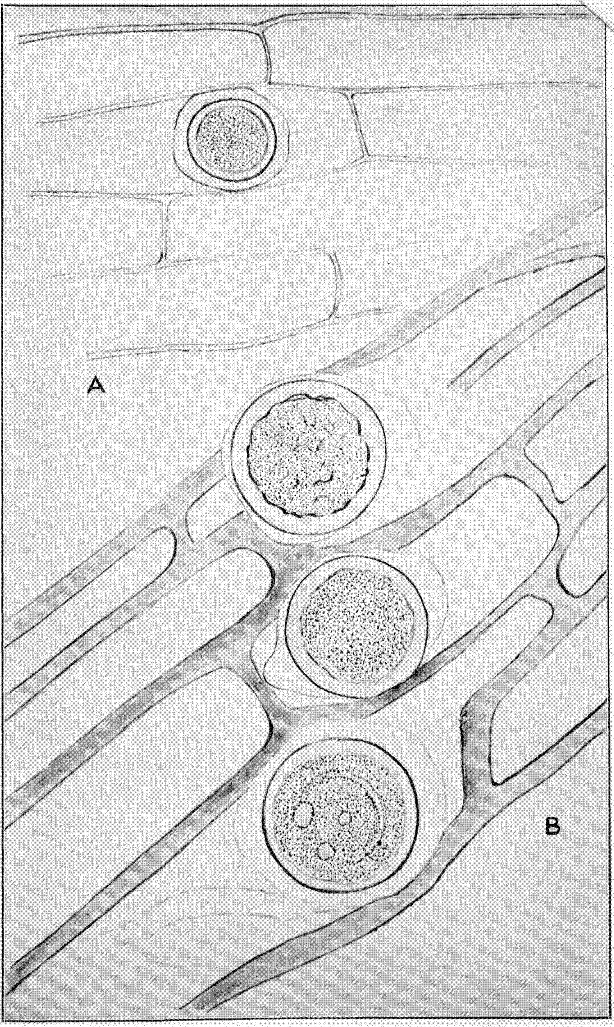
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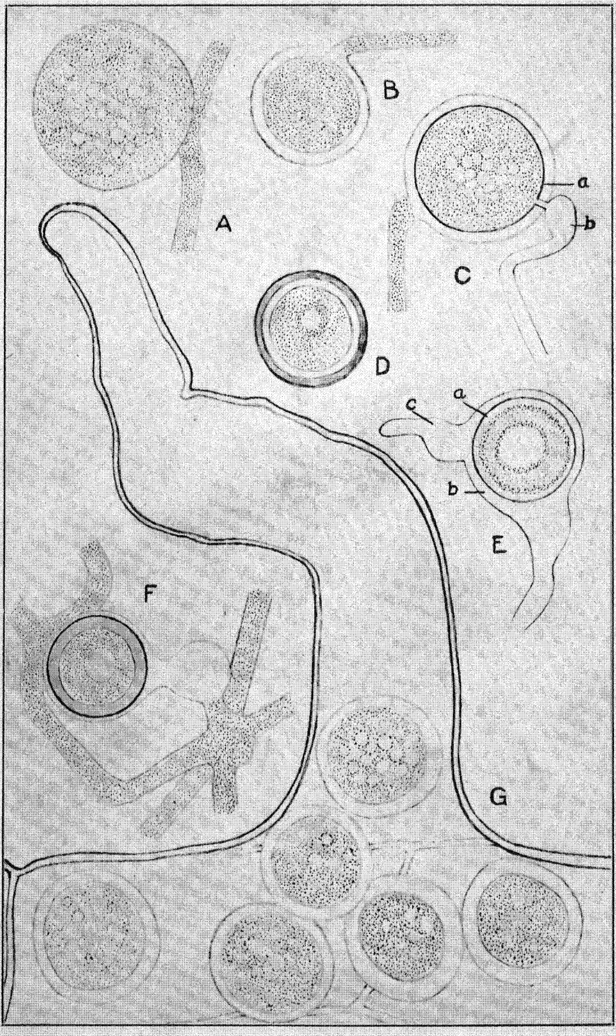
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